(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 189 279 B1**

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **09.10.91** (51) Int. Cl.[5]: **H05K 13/02**

(21) Application number: **86300282.0**

(22) Date of filing: **16.01.86**

(54) **Semiconductor processing system.**

(30) Priority: **22.01.85 US 693722**

(43) Date of publication of application:
30.07.86 Bulletin 86/31

(45) Publication of the grant of the patent:
09.10.91 Bulletin 91/41

(84) Designated Contracting States:
CH DE FR GB IT LI NL

(56) References cited:
US-A- 4 412 771
US-A- 4 457 661
US-A- 4 473 455

SOLID STATE TECHNOLOGY, vol. 28, no. 1, January 1985, page 74, Port Washington, New York, US; "Wafer handling robot"

(73) Proprietor: **APPLIED MATERIALS, INC.**
3050 Bowers Avenue
Santa Clara California 95051(US)

(72) Inventor: **Maydan, Dan**
12000 Murietta Lane
Los Altos California 97032(US)
Inventor: **Somekh, Sasson R.**
524 Compass Drive
Redwood City California 94065(US)
Inventor: **Ryan-Harris, Charles**
P.O. Box 328
La Honda California 94020(US)
Inventor: **Sellheimer, Richard A.**
420 Pine Hill Lane
Pleasonton California 94566(US)
Inventor: **Cheng, David**
974 Sherman Oaks Drive
San Jose California 95128(US)
Inventor: **Abolnikov, Edward M.**
7025 California Street, No. 201
San Francisco California 94121(US)
Inventor: **Reinke, Lance S.**
77 Park Sharon Drive
San Jose California(US)

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid (Art. 99(1) European patent convention).

Rank Xerox (UK) Business Services

Inventor: Moran, J. Christopher
211 Latham No. 307
Mountain View California 94041(US)
Inventor: Catlin, Richard M.
717 Galleon Lane
Foster City California 94404(US)
Inventor: Lowrence, Robert B.
3499 Bennett Avenue
Santa Clara California 95051(US)
Inventor: Ridgeway, George W.
1209 Sierra Village Way
San Jose California 95132(US)

(74) Representative: Bayliss, Geoffrey Cyril et al
BOULT, WADE & TENNANT 27 Furnival Street
London EC4A 1PQ(GB)

Description

The present invention relates to apparatus and methods for processing semiconductor wafers and, in particular, to a semiconductor wafer etching system in which robotic wafer handling in a vacuum load lock provides rapid, contamination-free loading and unloading of the wafers.

In implementing the dense, complex and contamination-sensitive LSI and VLSI integrated circuit structures, it is desirable, for throughput and particulate control, to utilize a plasma etching technology which employs automatic, batch-type, cassette-to-cassette wafer handling, both for offloading wafers from a cassette onto a wafer support electrode within the processing chamber, and for returning the wafers to a cassette after processing. Throughput and particulate control would also be enhanced by the use of vacuum load lock mechanisms which provide wafer loading and offloading of the wafer support electrode in a vacuum. Load lock mechanisms not only decrease pumping and processing time, but also decrease exposure of the LSI/VLSI structures to contaminants.

Full optimization of throughput and contamination-free wafer handling also requires wafer handling systems which can precisely pick up and release wafers per se without damaging the wafers and without generating particulates from the wafers themselves. Additionally, throughput and cleanliness require wafer handling systems which have the capability to automatically load and unload a wafer support electrode, with a minimum intrusion of particulate-generating mechanisms into the processing chamber. The wafer support electrode typically is polygonal in cross-section and has as many as six or eight wafer-support faces or facets. Such "hexodes" or "octodes" or other multiple-facet electrodes permit a large number of wafers to be processed simultaneously but also impose stringent requirements in precisely positioning and picking up the wafers at a multiplicity of positions on the different faces of the electrode.

Considering first, robotic wafer handling per se, the two robotic-type wafer grippers which are believed to be conceptually the closest existing designs in terms of satisfying the above objectives, were developed in the same time frame as the present invention and, thus, very well may not be prior art. However, these systems are described here because they are the closest known existing designs. One of these wafer chucks is the subject of commonly assigned, co-pending Jacobs et al U.S. patent application, Serial No. 591,439, filed March 20, 1984, entitled "FINGER CHUCK AND METHOD FOR HANDLING ARTICLES". The Jacobs et al wafer gripper or chuck comprises a plurality of pivoted fingers which cooperatively grip and release a wafer by its edge. Each finger is mounted near the arcuate base of one leg of a U-shaped leaf-spring and extends past the base. The second leg of the spring is mounted to a flat mounting plate. In addition to mounting a wafer gripping finger, the end of the first leg is also mounted to a common base plate and forms a radial configuration with the other spring-mounted wafer gripping fingers. Reciprocal movement of this base plate, either directly by an electromagnetic field or by a solenoid-operated or air-operated plunger, pivots the wafer gripping fingers closed and open about the spring mounting for gripping and releasing a semiconductor wafer.

The second relevant wafer gripper is part of a wafer handling system which is available from Applied Materials, Inc., Santa Clara, California. The wafer gripper and associated wafer handling system are disclosed in commonly assigned Flint et al, U.S. Patent No. 4,457,661, issued July 3, 1984. The Flint et al wafer loading/unloading technique involves removing wafer holding covers or trays from a reactor electrode and mounting them on a generally cylindrical carousel for automatic loading/unloading of the wafers from the inside of the carousel, that is, from the backside of the trays. In particular, the Flint et al '661 patent covers apparatus for transferring wafers between the trays and a pair of load and unload cassettes which are positioned inside the carousel and trays. The wafers are held on the trays by leaf-spring-mounted clips. The clips are pivoted open by depressor pins mounted on the wafer gripper for inserting and releasing the wafers. The carousel is rotated about its axis to position successive trays for wafer loading and unloading by the gripper assembly. The wafer cassettes are positioned on an elevator assembly and can be indexed both axially (vertically) for alignment with different wafer holding positions on the trays, as well as radially (horizontally) for positioning the two cassettes over a pair of associated wafer transfer blades. The transfer blades transfer the wafers vertically between the cassettes and the associated gripper assembly, which comprises a pair of vacuum chucks. The chucks in turn carry the wafer horizontally between the transfer blades and the wafer holding positions on the trays.

An example of the wafer clips disclosed in the Flint et al '661 patent is shown in FIG. 4A and designated 1 here. Similar clips are disclosed in Dean et al U.S. 4,473,455. The clip depressors used by Flint et al are attached to the vacuum chucks and move with the chucks to engage the clips from the backside of the tray and wafer. The clip depressors (see depressor 2 in FIG. 4A) engage and pivot the clips 1 about their transverse mounting springs 3 in a generally forward and

outward direction to open the clip array for gripping or releasing a wafer 4. This clip mounting and construction does not permit engagement from the front side. That is, engagement by the depressor pins 2 from the front side would merely pivot the clips 1 inwardly, closer together. This "closing" of the clip array would prevent loading a wafer 4 onto an empty tray position or, when a wafer is at the tray position, would result in the wafer being gripped even more tightly. In short, the clip construction and operation disclosed in the Flint et al '661 and in the Dean et al '455 patent are dedicated to backside loading/unloading of wafer trays, e.g., as described in the Flint et al patent itself, which necessarily involves loading/unloading at a distance from, rather than on, the reactor electrode.

Considering, next, wafer handling systems in general, several different types of approaches have been used for loading/unloading wafer support electrodes. One approach is to load and unload the hexode in the ambient atmosphere, either manually or using automated wafer handling. However, during atmosphere loading and unloading, the wafers and the processing chambers can be contaminated by particulates in the ambient atmosphere and by gases such as water vapor. In addition, this approach decreases throughput because the processing chamber vacuum is broken after each process sequence in order to unload and reload the wafers, and the chamber must then be pumped down to vacuum before starting the next processing sequence.

Another approach is to use a single-wafer processing chamber and load/unload the chamber from a load lock mechanism. This approach reduces contamination somewhat, but has the disadvantage of increased wafer handling time and reduced process quality or throughput.

Other approaches include loading multiple wafers on a planar electrode via a load lock mechanism, or onto a horizontally oriented electrode such as a hexode. However, to our knowledge none of the available load lock systems provides automatic, cassette-to-cassette wafer loading and unloading within the load lock onto a wafer-mounting electrode which is vertically oriented in its normal processing orientation. Loading and unloading a vertically oriented cathode is highly desirable because it reduces particulate contamination and allows a higher number of wafers per system floor space. The unavailability of such a system is, no doubt, due to the stringent wafer handling which are required of such a system.

This invention provides a robotic wafer handling system for transferring wafers bidirectionally between first and second angularly oriented positions, comprising a wafer gripper actuable for releasably gripping a wafer; wafer transfer apparatus including a support and means mounting said wafer gripper for extending and retracting movement relative to said support for loading and unloading wafers at first and second angularly oriented positions, the second position being a wafer loading and unloading position in a vacuum load lock chamber and the first position being a wafer loading and unloading position at the wafer support in the processing chamber and means for pivoting the mounting means of the gripper to orient the wafer gripper relative to the first and second angularly oriented positions, so as to orient the gripping finger means for loading and unloading at said first and second positions.

For example the first position may be at least one substantially vertically oriented wafer support position defined on wafer processing apparatus within a wafer processing chamber, and the second position may be a substantially horizontally oriented wafer support position having associated therewith separate wafer loading and unloading positions, the wafer handling system further comprising a wafer loading and unloading system which comprises indexing means adapted for supporting at least a pair of wafer holding receptacles such as cassettes so that the major surface of wafers therein are oriented horizontally and for selectively indexing the cassettes vertically through respective horizontal loading and unloading positions; and a shuttle comprising a wafer transfer blade having two flat horizontal wafer holding ends pivotally mounted for reciprocal horizontal pivoting of the two wafer holding ends between said second position and an associated one of said loading and unloading positions to locate one blade end at said second position for wafer transfer by the gripping finger means when the other end is at its associated loading or unloading position; and wherein said selective vertical cassette indexing movement through the horizontal loading or unloading position effects automatic wafer transfer between the cassette and said horizontal wafer holding sections of the transfer blade.

In a further arrangement the wafer support position may be on an electrode within a processing system, the wafer handling system may include clips for holding the wafers at the wafer support positions with the wafer backside adjacent the electrode, and the wafer gripper may include means for engaging the clips from the front side of the wafer support position for moving the clips to an open position to permit loading and unloading of the wafers at the electrode.

In a still further arrangement an optical sensor may be attached to the gripper for generating an electric signal representation of the distance between the gripper and the first position; computer means may be provided responsive to said elec-

trical signal for determining the angular orientation of the first position relative to the gripper and the distance between the first position and the gripper, the computer means including electronic memory for storing said angular orientation and distance information; and electronic driver means may be provided responsive to the stored information for controlling the wafer transfer apparatus to precisely move the gripper to the first position for loading and unloading wafers.

In a further construction the aforesaid first position may be a substantially vertically oriented wafer support position defined on wafer processing apparatus within a wafer processing chamber, and in the second position may be a substantially horizontally oriented wafer support position associated with a multiple wafer holder receptacle, and the wafer processing apparatus may comprise a wafer holding electrode having a plurality of substantially vertical sides, each side being adapted for supporting at least one wafer thereon, and being rotatable about a substantially vertical axis to selectively position the sides at the first position, and wherein each side of the electrode includes holders for mounting a plurality of wafers; and wherein the robotic wafer handling system may further comprise an elevator adapted for mounting the wafer transfer apparatus for vertical movement therealong, and means for moving the wafer transfer apparatus on the elevator between the plurality of vertical wafer holders.

In the latter arrangement the vacuum load lock chamber may be provided adjacent the processing chamber mounting the wafer transfer apparatus therein; and a gate valve may be provided between the wafer processing chamber and the load lock chamber for permitting transfer of wafers there between.

Further said support may be a housing having an base; a plurality of arms mounted on the hub for rotation on the base substantially transverse to their length; a plurality of means having first and second angled sections and being attached to the base at the first section and to the arm at the second section and mounting the wafer gripper arms thereto for converting transverse reciprocal rotation of the arm into substantially radial inward and outward translational movement of the wafer gripper arms for co-operatively picking up and releasing wafers; and means for rotating said hub.

In the case where the water support position is on an electrode within a processing system the electrode may be multi-faceted, each electrode facet being adapted for mounting a wafer support tray to expose one side of each wafer supported in the tray for processing; each tray including generally circular arrays of spring-mounted clips for releasably supporting each wafer; and the clips being adapted for engagement from the exposed side of the wafer and facet for pivoting the array to an open position for insertion and removal of wafers.

In one particular embodiment of the present invention a semiconductor wafer handling system for loading and unloading a vacuum processing chamber incorporates wafer support means, typically in the form of a vertical cylinder of polygonal horizontal cross-section. Each vertical wall or face of the wafer support is adapted for releasable holding a plurality of wafers. A vacuum load lock mechanism is mounted adjacent the processing chamber. A retractable gate valve between the wafer processing chamber and the load lock encloses the vacuum processing chamber and opens to permit the transfer of the wafers between the chamber and load lock.

Thus the arrangement enables a robotic wafer handling system to provide automatic, batch-type cassette-to-cassette wafer loading and unloading of a plasma etching/processing chamber using a vacuum load lock. Furthermore, the wafer handling system may be arranged to load and unload a vertical wafer-mounting electrode.

The robotic wafer handling system may also be constructed to meet very stringent particulate and contaminant requirements by virtue of the system design concept of (1) minimizing the generation of particulates and other contaminants by the constituent components or systems and (2) minimizing the transfer of contaminants between the various constituent systems/components.

In one specific construction the wafer handling system includes a wafer indexer, a shuttle blade and a robotic wafer transfer system or robot. These key components are all located within the load lock. The indexer, shuttle and robot cooperatively unload the wafer from containers such as cassettes onto the wafer support (hereafter "hexode") and off-load the wafers from the hexode and return the wafers to the cassettes.

Four transfer stations or positions are used for this cooperative reciprocal wafer transfer process. The wafer indexers mount separate containers, such as -- one cassette holds unprocessed wafers and the other receives processed wafers -- and indexes the cassettes past respective cassette unloading and reloading stations.

The shuttle reciprocally transfers wafers between the unloading/reloading stations and an intermediate third station (the "second position") where the wafers are picked up/deposited by the robot. The robot is adapted for Z translational movement and θ rotational movement about the center defined by the Z position and R translational motion from the center defined by Z along the direction defined by θ, for transferring the wafers between the horizontal third station and the vertical fourth

station (the "first position") at the hexode, where the robot deposits the wafers or removes the wafers.

In one particular arrangement, the shuttle blade is a two-pronged blade which is mounted for generally horizontal pivotal movement to position the blade ends at the first and third or second and third stations. Pivotal movement in one direction (e.g., clockwise CW) positions one blade in the loading cassette (first station) for removing the wafer from the cassette when the cassette is indexed down one position by the indexer, while the second blade is positioned at the third station for receiving a wafer which has been off-loaded by the robot from the hexode. Conversely, pivotal movement in the opposite direction (e.g., counter-clockwise, CCW) now pivots the off-loaded processed wafer into the receiving cassette at the unload station (second station) such that indexing of the cassette up one position lifts the processed wafer off the second blade. The CCW movement simultaneously presents the first blade and unprocessed wafer to the third station for pick-up by the robot.

As alluded to above, when an unprocessed wafer is presented to the third station, the robot extends towards and engages the horizontal wafer, retracts (as is necessary), pivots it vertically and moves in the R and Z directions to position the wafer at a selected wafer position at the hexode, then releases the wafer onto the hexode. The robot is then selectively indexed vertically in the Z direction into position for engaging and offloading a processed wafer from the wafer holder, pivots to orient the wafer horizontally and translates in the R direction to position the processed wafer at the third position, then releases the processed wafer onto the shuttle second blade for insertion into the unloaded cassette.

The arrangement of the present invention allows processing of wafers on a vertically oriented cathode with a selection between gravity hold and wafer clamping to provide the thermal connection between the wafer and the cathode. Both gravity hold and wafer clamping are provided in conjunction with automatic, in-vacuum, low particulate wafer handling. In another arrangement, the abovementioned wafer clamping function is provided by an improvement of the clips disclosed in the Flint '661 patent. The present wafer-holding clips are designed to be actuated by clip depressors from the front or processing side of the electrode/hexode covers, consistent with the object of performing wafer loading/unloading with the covers mounted on, rather than removed from, the electrode.

The design of the robotic, in-vacuum wafer loading and unloading system and components decreases the intrusion of particulate-generating moving mechanisms into the processing chamber and thereby minimizes contamination of the wafers and the chamber environment. Particulates are minimized by a load lock chamber filter system, which includes a robot housing filter which prevents the transfer of particles between the robot and the surrounding load lock chamber. This filter system also includes a vent inlet line filter and a roughing outlet/exhaust line filter which isolate the load lock chamber from the vent gas supply and the roughing vacuum system and, together with the use of a sequenced venting and roughing approach, establish non-turbulent, laminar, particulate-free fluid flow during venting and roughing.

The robotic wafer handling combined with the load lock allows batch processing of wafers in a process chamber which is kept continually at vacuum to exclude the ambient atmosphere – including contaminants, particulates and water vapor – from the process chamber.

The above-described system also combines the advantages of a load lock with those of an automatic wafer handling system and a vertically oriented batch plasma etching process.

In still another arrangement, the unique thermally-isolated mounting of the robotics to the processing chamber sub-frame minimizes thermal stress and strain on the robotic wafer handling system, yet maintains alignment of the system relative to the processing chamber and pedestals and thereby provides stable positioning of the wafer handling system despite different thermal conditions in different parts of the overall system.

The present system uses an electronic memory map of electrode pedestal position and orientation data, derived from an optical sensor on the robot, to effect the precise autoloading and unloading of wafers at the pedestals.

The features described above cooperatively provide low contamination, fast, automatic, large volume, cassette-to-cassette batch wafer handling which is ideally suited for high throughput, fine geometry VLSI wafer processing technology.

The following is a specific description of a specific embodiment of the present invention references being made to the following drawing figures, in which:

FIG. 1 is a side elevational view of the present semiconductor processing system, shown partly in section and schematically;

FIGS. 2 and 3 are, respectively, front elevation and vertical cross-section views of a hexode cover which includes the wafer gripping clips of the present invention;

FIG. 4A is an enlarged fragmentary section view of a prior art wafer holding clip;

FIGS. 4B and 4C are enlarged fragmentary sectional views taken along the lines 4-4 in FIG. 2

illustrating the construction and operation of the wafer-holding clip of the present invention;

FIG. 5 is a slightly enlarged depiction of the overall semiconductor processing system, similar to FIG. 1, emphasizing different features of the system;

FIGS. 6 and 7 are, respectively, a right-side elevational view and a left-side elevational view of the load cassette indexing mechanism and the unload cassette indexing mechanism;

FIG. 8 is an end view of the load indexer of FIG. 7;

FIG. 9A is a top plan view of the shuttle blade mechanism;

FIG. 9B is a section view taken along line 9B-9B in FIG. 9;

FIGS. 10 and 11 are, respectively, a bottom plan view and an end view of the shuttle blade mechanism of FIG. 9;

FIGS. 12A and 12B schematically depict operational views of the shuttle blade;

FIG. 13 is a top plan view of the robot shown with the housing cover removed;

FIG. 14 is a sectional view taken along line 14-14 in FIG. 12;

FIGS. 15A and 15B are orthogonal elevational views of the robot elevator assembly;

FIG. 16 is a rear elevational view of the wafer gripper;

FIG. 17 is a front elevational view of the wafer gripper;

FIG. 18 is a side elevational view of the wafer gripper showing the clip depressors;

FIG. 19 is a schematic representation of the four-bar link construction of the wafer gripper;

FIG. 20 is a block diagram of the autoloader control system;

FIG. 21 is a block diagram which schematically depicts the gripper controller and memory mapping system (autoaligner); and

FIG. 22 is a graph of the reflected photocurrent characteristics associated with the sensor of FIG. 22.

FIG. 1 illustrates a preferred embodiment of the present invention in the form of a semiconductor processing system 5. The illustrated system is a plasma etcher which includes a vacuum processing chamber 6 and a vacuum load lock chamber 7, both of which are mounted on frame 8. The automated wafer loader (loading and unloading) system of the present invention is contained within the load lock chamber 7. Access between the wafer processing chamber 6 and the load lock chamber 7 is provided by a conventional gate valve assembly 9. The gate valve forms an opening between the two chambers and contains a retractable door (not shown) which, when extended, seals the opening between the vacuum processing chamber 6 and the load lock chamber 7 and, when retracted, provides access by the load lock wafer handling system to a wafer-holding hexode 18 within chamber 6. The wafer etching system 5 may also include a microprocessor control system, display screen and keyboard, designated collectively by the reference numeral 10, which can be used to control the operation of the various sytems and components.

Plasma Chamber Construction and Operation

Referring further to FIG. 1, the processing chamber 6 which is the subject of the present invention is a radio frequency (RF) plasma etching chamber. The chamber 6 is mounted on a process chamber base plate 11. The chamber 6 comprises a cover assembly which includes a fixed base 12 and a cover 14 which is pivotally mounted at 15 and is opened and closed by a pneumatic cylinder 16. Integrated circuit wafers 17 are supported in the chamber 6 for processing on a vertical cylindrical electrode 18 which typically has a polygonal horizontal cross-section. The illustrated hexagonal electrode or "hexode" 18 comprises six removable, generally vertical, aluminum oxide-coated aluminum faces or covers 20-20, each of which has three bores 21-21 in which are mounted wafer support pedestals 22-22. See FIGS. 2 and 3. The hexode 18 is mounted for rotation about a vertical axis within the chamber. An electric motor 23 is mounted within the base compartment 8 and has an indexing assembly 24 which is coupled into the chamber 6 by a conventional vacuum rotational seal (not shown) and is connected to the base of the hexode for rotating the hexode. The processing chamber base and cover and the other major structural components of the RF wafer processing system 5 are aluminum or stainless steel. The base 12, cover 14, retractable door, and process chamber base plate 11 form the anode in the RF processing system.

As shown schematically in FIGS. 1 and 5, gas inlet tubes 25-25 are mounted adjacent each hexode face or cover 20 for supplying etching gas to the chamber 6. The purpose is to develop an etching plasma in the chamber RF field which is applied between the cathode 18 and the chamber wall/anode 12,14. Reactant gas is applied to the inlet tubes and the chamber from a gas supply system which includes a number of gas storage tanks or reservoirs (not shown) which supply gases through gas control system 28 to the inlet tubes 25-25. The control system 28 may be composed of a plurality of mass flow controllers. Power is supplied for creating an etching plasma from the reactant gases by an RF system, which includes a remote RF generator and a load matching network 30, and which is connected to the hexode 18. A

turbo-molecular pump 31 connects chamber exhaust 32 to a remote pumping system (not shown) via exhaust line 33 for evacuating the processing chamber 6 to subatmospheric pressure. Also, vacuum is applied to the load lock chamber 7 by a cryo pump 34 and a remote roughing pump which is connected to exhaust line 35.

The roughing system includes valve 36 in regular roughing line 37 and valve 38 in bypass/slow roughing line 39. These two valves are used to select between high flow rate regular roughing over line 37 (valve 36 open; 38 closed) and relatively low flow rate, slow roughing over the smaller diameter slow roughing line 39 (valve 38 open; 36 closed).

An enlarged view of an individual hexode face or slab 20 utilizing clamp means is shown in FIGS. 2 and 3. The individual hexode faces or slabs 20 are removably mounted on a hexode frame 43 by screws 44-44, thereby interconnecting the faces electrically. Interchangeable pedestals 22-22 of different sizes and/or materials can be mounted within the bores 21 by screws 45-45 and used for processing wafers 17 (FIG. 1) of different diameters. Each pedestal 22 is mounted to the hexode at a slight angle from the vertical, approximately 3° Pedestal rings 46-46 are mounted by screws 47-47 to the pedestals 22-22. A pair of wafer support buttons 48-48 are mounted on the bottom section of each pedestal ring so that the wafers are retained on the pedestal by gravity.

In etching material such as aluminum, the gravity-induced contact between the wafer 17 and the inclined pedestal 22 provides adequate heat transfer to uniformly cool the wafer and prevent thermal-induced effects. The greater amounts of heat produced by processes such as oxide etching may require more forceful, uniform pedestal-to-wafer contact for adequate thermal conduction and wafer cooling. That is, some form of external clamping must be used. This thermal transfer clamping function must be provided consistent with the object of totally automated, in vacuum wafer handling.

Wafer Clips

Referring to FIGS. 2, 4B and 4C, the above objective is satisfied by the use of wafer clips 50-50 which provide the necessary contact pressure, yet automatically release from the wafer to permit loading and unloading of the pedestal by the system wafer handling robot with a minimum of particulate generation. In the preferred arrangement shown in FIG. 2, the support buttons 48-48 are used to hold the wafer during the time when the robot is releasing wafers 17 onto the pedestal or picking up wafers from the pedestal front or processing side of the wafer cover 20. See also FIG. 5. At other times, the wafers 17 are secured to the pedestal by the plurality of clips 50-50, (typically four per pedestal). Each clip 50 is mounted by a screw 52 to a flat spring 54 which in turn is mounted to a support block 56 on the pedestal by a screw 58. The spring 54 extends generally transverse (-90°) to the plane of the cover 20. Due to this mounting arrangement, the spring 54 and clip 50 pivot at or adjacent the spring mounting point 58 and the clips are normally biased by the springs to uniformly clamp the wafer 17 against the pedestal, as illustrated schematically in FIG. 4B.

The illustrated embodiment uses four clips 50 which are individually pivoted outward by the arms 64-64 of the wafer handling robot 60, as shown in FIG. 4C, to permit the robot to release the wafer to the pedestal 22 for engagement by the clips and to permit the robot to engage and remove the wafers from the pedestal. The illustrated "Z clip configuration provided by the actuating arm 62 and the clip-engaging arm 63 and the clip dimensions are selected to minimize particulates created by robot actuation: the angled, approximately 45° flat front surface 59 contacts and holds the wafer in place without undue stress; the actuating step or arm 62 is positioned close to the pivot point 56 of the clip to minimize the angle between the clip and the robot actuator arm 64 as well as the distance traveled by the robot and the clip step in rotating the clip. These features minimize particulates caused by contact between the arm 64 and the step 62. In addition, the flat spring 54 pivots without surface contact and is designed to securely clamp the wafer to the pedestal over the entire wafer surface without damaging the wafer and using a stress which is only about 60-65 percent of the spring's yield strength. In the illustrated embodiment, the desired stress level is provided by a spring which is about 0.5 inches long x 0.2 inches wide x 0.004 inches thick, and is rotated a maximum of about 30° between loading and unloading. As a consequence of these features, the robot actuator clip 50 operates with a controlled, uniform low clamping force without damage to the wafer or its coatings and is activated from the front side of the cover 20 by the robot to engage and release the wafer with the cover in situ on the hexode 18 and with a minimum of particulate generation. The clip is also transparent to the magnetic field and therefore does not interfere with the uniform plasma generation. Those of skill in the art will readily vary the number and orientation of the clips to accommodate different requirements.

Automatic Wafer Handling System

Referring to the schematic, partial left side

elevational illustration of the system 5 shown in FIG. 5, the wafer handling system or "autoloader" is enclosed within the vacuum load lock chamber 7. The loader includes an indexer system 66 which includes a two-cassette capacity unloading indexer 68 (FIG. 7), a two-cassette capacity loading indexer 67 (FIG. 6), shuttle or wafer transfer mechanism 70 (FIGS. 9-11), flat finding mechanism 71 (within the reloading indexer) and the four-axis wafer transfer robot 60 (FIGS. 12-17, 19). The indexers 67-68 of indexer system 66 are each mounted on the interior side of individual vacuum doors 82-82 which are pivoted opened and closed by pneumatic/hydraulic cylinders 84-84. See FIG. 1. When closed, the doors form part of the wall of the vacuum chamber 7.

With the vacuum doors 82-82 open, the standard wafer cassettes 72 in the horizontal indexers 67 and 68 are unloaded and new cassettes 72 are loaded onto the indexers (empty cassettes in unload indexer 68, FIG. 7; cassettes with wafers to be etched in load indexer 67, FIG. 6), with the wafers in a vertical orientation. The flat finding mechanism 71 is a conventional roller mechanism 74 which is mounted beneath the load cassette and connected by coupling 75 to drive motor 76 for rotating the wafers within the conventional open-bottom cassette so that the flats are at the bottom dead center (BDC) location.

After the flats are oriented, the indexer 82-82 doors are pivoted shut vertically by the cylinder assemblies 84-84 so that the wafers in their cassettes are rotated to a horizontal orientation for loading and so that the vacuum chamber is sealed. The wafers 17 in the loading indexer 67 are sequentially removed by the wafer shuttle 70 and brought individually to a transfer station 73 (FIG. 12A beneath the four-axis robot 60. The robot picks up a wafer from the shuttle 70 at the station 73 and places it in a selected one of the three cathode pedestal locations 22A-22C (FIG. 5) on the hexode face 20 facing the robot. Robot 60 also sequentially removes wafers from the cathode and places them on the shuttle at the station 73 (FIG. 12B) for transfer by the shuttle to the unloading indexer 68. Thus, at the start of operation, i.e., with an empty hexode 18, the robot 60 loads wafers from the load cassette 67 onto the pedestals 22. After a previous processing sequence, the robot unloads then loads each pedestal position before moving on to the next pedestal position and, then, the next hexode face. The wafers are handled by their backside and edges in such a manner, described below, that the wafer edge contact forces are limited to about eight ounces, causing no damage to the resist bead that is often present at the edge of the wafer. Also, the wafers are handled in vacuum only.

Indexing System

As mentioned, the indexing system 66 includes a two-cassette capacity load indexer 67 and a two-cassette capacity unload indexer 68 which are indexed to position the respective cassettes at a respective loading position (also designated 67) and unloading position (also designated 68) for off-loading and loading of the cassettes by the wafer.

Referring specifically to FIGS. 6-8, each indexer 67-68 includes a pair of guide rails 83-83 which are mounted to the associated load lock door 82. The doors 82-82 are opened and closed by pneumatic/hydraulic cylinders 84-84 (FIG. 1). The doors 82 provide access to the load lock chamber 7 and also mount the cassettes 72 for vertical indexing past the respective loading/unloading positions. The cassettes 72 are standard multiple wafer cassettes and are supported on conventional dual cassette mounting fixtures 85. Each fixture is slidably mounted on the pair of guide rails 83-83 and mounts, and is indexed by, a conventional power screw drive 86 (FIG. 8) which is driven by an associated stepper motor 87 operating via a drive belt 88. When the doors 82-82 are pivoted to the open, approximately horizontal orientation by the cylinder 84, the existing cassettes are unloaded from the indexers, and load indexer 67 is loaded with cassettes containing wafers which are to be processed, while unload indexer 68 is loaded with empty cassettes. When the load lock doors 82-82 are pivoted closed by the cylinders 84-84, the doors become part of the vacuum tight load lock chamber wall 7 and also position the cassette indexing system for vertical indexing of the cassettes by the stepper motors 87 to position the horizontal wafers in seriatim at the loading position 67 and to position the horizontal receiving cassettes at the cassette unload position 68.

Shuttle

Referring to FIGS. 9-12A, 12B, the wafer transfer mechanism or shuttle 70 comprises a base 89 which is bolted to the load chamber base plate 13 (FIG. 1). A generally T-shaped, dual ended blade 90 is mounted to the base 89 for approximately 90° reversible rotation between the load position 67, the robot transfer position 73 and the load position 68, and vice versa. The T-shaped blade 90, shown most clearly in FIG. 9, includes an unload end 90U and a load end 90L. The arm 90S of the angled blade is mounted for reciprocal pivotal rotation on an air cylinder-operated shaft 92. See also FIG. 9A. As shown in FIGS. 10 and 11, a pair of air cylinders 94 and 96 are pivotally mounted on the frame 89 at 97 and 98 and are coupled to the shaft 92 by crank arm 99 at 99A and 99B,

respectively, for pivoting it. Cylinder 94 is a travel cylinder which pivots the shaft 92 and blade 90 between the cassette unload and reload positions 67 and 68. Air cylinder 96 is a "home" cylinder which returns the blade 90 to an intermediate, center position when the travel cylinder is released between transfer operations. Cam 91 is fixedly mounted on base 88. A pair of cam followers 101-101 are mounted one on each blade 90U, 90R, at 102-102. Each cam follower mounts a roller 104. The cam 91 is configured so that during pivotal movement of the blades, the rollers 104 cause the blade ends 90U or 90R to describe a generally curved path, with a transition to a substantially straight path during entry into and retraction from the cassettes. This path 100U, 100R facilitates accurate removal and insertion of the wafers from and to the cassettes without damage.

Referring further to FIGS. 9, 12A and 12B, and in particular 12A, clockwise pivoting of the transfer blade 90 positions load end 90L at the load position 67 preparatory to picking up an unprocessed wafer from the load cassette, while the second, empty unload end 90U is positioned at transfer position 73 to receive from the robot 60 a wafer which has been off-loaded from hexode 18. As shown particularly in FIG. 12B, counterclockwise pivoting of the blade 90 positions the unload end 90U at the reload position 68 for transferring the off-loaded wafer to the "finished processing" or unload cassette and positions the unprocessed wafer on the load end 90L at position 73 for transfer to the robot 60 for loading onto the hexode 18.

Robotic Wafer Gripper 60

Referring to FIGS. 13 and 14, the four-axis robot 60 includes a housing or enclosure 110 which mounts a wafer gripper head or chuck 120. The housing is supported for vertical or Z-axis movement by an elevator shaft 124 and guided from rotation by shaft 122, which are shown in FIGS. 15A and 15B. Guide shaft 122 is fixedly mounted to the process system subframe 19 (FIG. 5). The other shaft 124 is coupled to the fixed shaft by a conventional power screw drive mechanism 126 which is also mounted to the subframe 19 and actuated by a belt 128 driven by motor 130 for moving the shaft 124 vertically up and down. The movable shaft 124 extends through a ball bushing pair in ball bushing housing 132 mounted to the subframe and a bellows seal 134 mounted between the housing 132 and the load chamber base plate 13 of the load lock chamber 7. Controlled reciprocal vertical movement of the movable shaft 124 moves the attached robot 60 and gripper head 120 between the three pedestal off-loading/loading positions 22A, 22B, 22C associated with each pedestal face 20. See FIG. 5.

The timing belt housing 110 (FIGS. 13 and 14) is pivotally mounted on horizontal shaft 126-126. Pivotal (θ) movement of the housing 110 about the shaft 126 is effected by a stepper motor and harmonic drive speed reducer 128, which is mounted to the mounting bracket assembly 129 affixed to elevator shaft 124 (FIG. 15A). Actuation of the reversible θ motor 128 rotates the housing and wafer gripper head approximately 90° counterclockwise (FIG. 5) to move the gripper from the vertical pedestal positions 22 into angular alignment with the horizontal position 73 to off-load a wafer from the pedestal onto the shuttle 70. See also FIG. 5. Clockwise rotation moves the gripper from alignment with the transfer position 73 into vertical alignment with the pedestal positions 22 to transfer a wafer from the blade to the pedestal.

Referring further to FIGS. 13 and 14, the wafer gripper head 120 is mounted at one end of a pair of support rods 142-142 which are slidably supported by four linear ball bushings 144-144, two each in one end of the housing 110 and in housing frame member 145. The support rod assembly is attached to a belt drive 146 at 148. The toothed belt 146 is mounted over idler pulleys 150, 152, passes beneath pinch rollers 154-154 and is reversibly driven by a cog wheel 158 which is driven by motor 149. The belt 146 is also attached to support bar 147 for the rods 142-142, at 148. Thus, reversible rotation of the R motor 149 advances the rods 142 and head 120 to pick up or unload a wafer 17 at the selected pedestal position 22A-C or transfer position 73, then retracts the head preparatory to rotation and transfer to the transfer position 73 pedestal position 22A-C.

Referring to FIGS. 16-18, as well as FIGS. 13 and 14, the wafer gripper head 120 itself includes a transparent circular base 160 which is attached to the front end of the support shafts 142-142 by coupling/collar 161. A front cover 162 is attached to the base 160 by means of mounting blocks 178-178 which also attach gripping arms 168 to the base 120. A gear reduction electric motor 164 is mounted to the rear of the base so that its drive shaft extends through the base 160. A hub 166 is mounted on the shaft and has a plurality of the gripping arms 168-168 extending therefrom parallel to the base. Each arm 168 has a wafer gripper finger 170 which extends transversely from the end of the arm typically at about a 90° angle relative to the arm, past the front of the base. The gripper arms 168 are connected to the hub 166 and the hub is connected to the motor drive shaft as part of a four-bar link arrangement which converts rotation of the shaft and the hub 166 into substantially linear radial movement of the arms 168-168. The reversible radial movement of the arms causes the

fingers 170 to cooperatively extend and retract to pick up and release wafers 17 by edge contact.

Referring primarily to FIG. 17 and FIG. 19, the approximately parallel-piped four-bar link configuration is provided by mounting the gripping finger arm 168 in spaced relationship to the axis 167 of pivotal hub 166 by mounting arm 168 to link 180 which is connected to an arm or link 172 which is an integral part of the hub 166; and by a third arm or link 174 which is attached at one end to the link 180 at arm 168 and at the opposite end to the base 160 at 175. In the illustrated wafer gripper, the link 174 is actually one arm of an L-shaped flexible member 176. The link 174 is attached by screws to the mounting block 178, which is rigidly attached to the base 160 by a pair of screws. (Please note, mounting block 178, FIG. 17, forms point 175 in the FIG. 19 schematic.) The other arm 180 of the L-shaped member 176 is attached to the hub 166 and forms a resilient base for the partially overlapping gripper arm 168, which, as mentioned, is mounted thereon. The L-shaped member 176 is, in effect, a flexible spring which can pivot slightly at the mounting block 178, at the intersection of links 180/174, and at the intersection of links 180/172, to provide the necessary movement for converting reversible rotation of the hub 166 into radially inward/outward movement of the cooperating gripping fingers. As shown in FIG. 19, the described construction provides a four bar link in which the input link is arm/link 172 and the non-moving link is defined between the gripper hub axis 167 and the attachment point 175 of arm/link 174. This arrangement provides movement of link 180 and wafer gripper arm 168 which is approximately parallel to the non-moving link defined by points 167 and 175.

Venting and Roughing System

One very rigorous objective of the present wafer etcher system is to minimize contaminants. The desired contamination-free, particulate-free environment is achieved, first, by minimizing the susceptibility to contamination of the individual steps or stations of the wafer handling system (including particulate generation during the operation of the individual stations) and, secondly, minimizing the transfer of contaminants from one station to the next.

The first aspect, that is, minimization of the introduction or generation of contaminants, derives from the previously discussed design and operation of the individual system components or stations. In this respect, the robot 60, the indexer assembly 66, and the shuttle 70 are designed to perform their individual wafer handling functions without introducing contaminants into the system, either as a result of their mechanical operation per se (for example, due to frictional contact between internal moving parts) or as a result of contact with the wafers. Performing the entire, cassette-to-cassette loading and unloading operation in a load lock system 7 also greatly decreases the introduction of contaminants during the wafer handling process.

The load lock 7 per se is also critical regarding the second aspect, that is, isolation of one system or station from the contaminants generated by another system or sequence or station. The overall roughing system, described previously, and the system for venting nitrogen into the load lock chamber when vacuum is broken are designed to establish laminar fluid flow, which does not pick up or transfer particles. Referring again to FIG. 1, the nitrogen vent system includes nitrogen supply line 181 which incorporates valve 183 and fixed diameter venturi 185. Line 182 includes valve 184 for bypassing venturi 185 and associated valve 183.

In operation of the nitrogen vent system, with valves 183 and 184 open and closed, respectively, nitrogen flow is through the venturi restriction and at a relatively low flow rate (slow venting). With valve 184 open and valve 183 closed, the bypass line 182 provides an unrestricted high flow rate (regular venting).

Similarly, as described previously, roughing valves 36 and 38 provide slow and regular roughing operation.

During slow venting/roughing operation (and partly as the result of the system filters described below), laminar fluid flow is established into/out of the load lock chamber, rather than turbulent flow, because of the slower flow rates provided by the slow rough and slow vent lines. During laminar flow, the velocity of the fluid flow along surfaces in zero, whereas for turbulent flow viscous forces associated with the non-zero velocity of the fluid can pick up and transfer particles. For the zero velocity associated with laminar flow, there is no viscous force present to pick up any particles. Thus, the use of an initial slow venting/roughing cycle preceding the regular venting/roughing cycle substantially eliminates the transfer of particulates within the load lock system onto wafer surfaces.

Filter System

The load lock 7 and robot 60 include a unique filtering system which, among several features, (1) confines any particulates generated within the robot housing 110 to that housing, and thereby avoids the use of an atmospheric pressure housing which must be vacuum sealed from the load lock chamber, and (2) removes particulates from the load lock chamber itself and (3) cooperates with the slow vent and slow rough operations to provide laminar, non-turbulent ambient gas flow within the

load lock.

Referring to FIGS. 1 and 14, the filter system includes three replaceable filters. The first filter 186 is mounted within an orifice 187 on the bottom side of the robot housing 110, (FIG. 14), whereas the second and third filters are cylindrical filters 188 and 189 which are mounted respectively on the load lock venting system inlet line 181 and to the vacuum roughing line 37.

The first, robot filter 186 permits the robot housing 110 to be maintained at the same pressure as the load lock chamber itself, yet isolates these two enclosures (housing and load lock) from one another in the sense of preventing transfer of contaminants. The robot housing filter 186 filters particles down to 0.000004 inch ($4x10^{-6}$ in.) diameter in size and therefore permits the passage of gas between the housing enclosure and the internal load lock chamber itself. Thus, any particulates generated within the robot housing 110 are confined to the enclosure. This is particularly important during the venting of the load lock chamber to atmospheric pressure and during pumping down of the load lock chamber to vacuum, since gas flow in and out of the housing could otherwise transfer particulates generated within the housing into the load lock chamber itself. The robot filter 186 comprises electrostatic filter material which in addition to this normal filtering action, also traps and retains particles from the ambient. Thus, in addition to confining to the housing 110 any particulates or contaminants which were generated within the housing, the filter 186 also removes and traps contaminants from the housing ambient and has the added advantage of trapping and removing particles from the load lock chamber ambient. In short, the robot filter 186 both prevents the introduction of particulates from the robot housing into the load lock chamber, and also lowers the existing particulate level within the load lock chamber by trapping particles which come into contact with the filter during random circulation and during venting-induced and vacuum-induced gas flow into and out of the robot housing 110.

In permitting a vacuum robot chamber which communicates with the load lock chamber without contamination, this filter approach avoids the necessity of placing a sealed, atmospheric pressure robot enclosure within the load lock chamber. Such a system would require, for example, vacuum-tight sliding seals for each of the robot support shafts 142-142. Such a system would also present the ever present risk of seal deterioration or failure allowing air to leak from the relatively high pressure of the robot housing into the low pressure of the load lock chamber and forcing particles into the load lock chamber.

The cylindrical vent filter 188 is mounted on the pressurized gas (nitrogen) inlet 181 which is used to bring the chamber up to atmospheric pressure. This filter eliminates particulates from the inlet gas flow. Similarly, the cylindrical roughin filter 189 is mounted on the "rough" vacuum exhaust line 37 for isolating the load lock chamber from the roughing system. In addition, these two filters slow down and control the inlet and exhaust air/gas flow, making the flow less turbulent and more laminar. This decreases the inherent tendency of turbulent gas flow to stir up and/or generate particles in the load lock chamber itself which can then be transferred onto the wafer handling apparatus and the wafers themselves.

The two filters 188 and 189 operate as follows to contribute to non-turbulent laminar flow. As will be appreciated, the flow rates through the inlet line 181 and through the inlet filter 188 are equal. Similarly, the flow rates through the roughing filter 189 and the vacuum roughing outlet line 37 are equal. However, the area of the approximately one-inch diameter inlet 37 (0.8 sq. in.) is much less than the total area of the 3 inch diameter x 8 inch long cylindrical inlet filter 186 (75 sq. in.). Similarly, the area of the two-inch diameter roughing outlet line 37 (3.14 sq. in.) is much less than the overall area of the 4 inch diameter x 12 inch high cylindrical roughing filter (150 sq. in.). For the equal flow rates, the velocities through the pipes and respective filters are inversely proportional to the areas. Thus, the inlet velocity is slowed by a large factor in traversing the inlet filter 188 and the roughing vacuum velocity is similarly slowed by a large factor in traversing the roughing filter 189. The filter media also slows the flow of gases that pass through them. As a consequence, turbulet flow at the pipes 37 and 181 is reduced, as is the tendency to stir up or knock off particulates within the load lock chamber.

In a presently preferred working embodiment, the robot housing filter 186 is a 2 inch diameter electrostatic filter available from Minnesota Mining and Manufacturing Company as filter type 6 Filtrete No. 4143. The inlet filter 188 is a 3 inch diameter x 8 inch long Millipore cylindrical filter. The roughing filter 188 is a 4 inch diameter x 12 inch long Millipore cylindrical filter. Tests of the system have shown that, on the average, no particles greater than 0.000040 inch diameter in size are generated during each cyle on the wafer.

Autoloader Operation

Referring now to FIGS. 1 and 5, the system base plates 11, 13 and the process subframe 19 cooperate in maintaining precise dimensional relationships between the wafer handling system and the hexode for the robotic loading/unloading oper-

ations. This is particularly advantageous when automated loading (autoloading) with position memory mapping is used. To minimize thermal-induced and pressure-induced interaction and distortion, the separate base plates 11 and 13 are used. The base plates are connected by the plates 190, FIG. 1, to restrict the number of degrees of freedom to one of rotation only and keep the base plates from moving. The processing chamber subframe 19 is constructed of standard structural tubing or bars in the configuration outlined in FIG. 5, is mounted to the processing chamber base plate at 105-105, and extends under the loading chamber Z-axis and supports the robot 60. The subframe 19 makes the robot an extension of the cathode 18 and minimizes any dimensional changes or distortions between the robot and the cathode which could otherwise result from pressure and temperature differences between the processing chamber and the loading chamber.

The controller-controlled operation of the autoloader is discussed below. The operational details of the indexer 66, shuttle 70 and robot 60 have been discussed in detail above. The description here is based upon the use of the controller 10, specifically a VME (Versa Modular European) system controller. The controller 10 (FIG. 20) includes a 16 bit 68000 microprocessor 191 which is interfaced via VME address and data buses 192-192 to a step motor controller circuit 193 and an encoder counter 194. The step motor controller circuit 193 comprises the CY525 IC chip which is available commercially from Cybernetics, San Gregorio, California. The encoder/counter 194 is a standard up/down counter. The controller typically can also include high speed memory capacity in the form of dynamic random access memory (DRAM), erasable read only memory (EROM) for system programs, static RAM (SRAM) battery back-up memory and non-volatile, electrically alterable EEPROM memory 195 for use in position memory mapping, described subsequently.

Responsive to the ASCII motor control commands, the step motor controller 193 provides a train of four phase motor clock and direction drive signals to the bipolar chopper driver 196, which provides power signals to the windings of reversible step motor 197 to control the operation, including direction, of the motor. In the present embodiment of system 5, five step motors 197 are used: one each to control R, θ, and Z robot movement and load and unload indexing. Commercially available digital shaft encoders 198 -- specifically guadrature optical encoders -- are used to provide direction and clock signals to the encoder buffer board 199, which "squares" the waveform of the signals from the encoders for input to the encoder counter 199 for use in controlling step motor operation. Conventionally, the direction signals are used by the encoder counter to decrement or increment the count.

As indicated at 101, controller 10 of the autoloader control system also provides digital signals for controlling the operation of solenoid valves which control the travel cylinder (unload and load sides) and home cylinder, described previously; operate the shuttle blade, and control the load lock chamber doors 82-82. Other digital signal lines control transistor switching circuits 107 which control the opening and closing operation of the gripper motor. As shown schematically at 102, digital input signals from redundant infrared blade sensors associated with the shuttle blade 90 provide fail-safe monitoring of whether wafers are on/off the load and unload blades to permit stopping of the autoloader operation. Finally, as discussed more fully below, amplified analog signals from the sensor 104 of gripper 120 of the autoaligning system 103 are converted to digital signals by A/D converter 106 for autoalignment and memory mapping of the robot 60 and hexode wafer (pedestal) positions.

Initially during autoloader operation, and referring to FIGS. 1 and 5, with the doors 82-82 held in the horizontal opened position by their respective cylinders 84-84, the cassettes from a previous processing operation are removed from the indexers 67,68 and replaced with cassettes containing wafers which are to be etched, in the case of the load indexer 67, and with empty cassettes, in the case of the load indexer 68. The wafers are conveniently oriented by the flat finding mechanism 71 so that the flats are in a bottom down center position. Then, the cylinders 84-84 are actuated to pivot the doors 82-82 closed to seal the load lock chamber 7 and pivot the indexers 66,67 to the vertical indexing position with the wafers oriented horizontally. At this time, the process chamber 6 is under vacuum. The load chamber 7 is first roughed by the remote roughing pump through filter 189 and rough vacuum line 37, then final pumped by the cryo pump to a pressure of 0.1 mTorr. When this pressure is reached, the gate valve 9 is opened allowing full communication between the chambers 6 and 7.

Referring also to FIGS. 12A and 12B, initially, the travel cylinder of the shuttle 70 pivots the blade 90 clockwise to so that the load blade 90L is in position 67 and the unload blade is at transfer position 73. At this position, the load cassette 67 indexes downwardly to load an unprocessed wafer onto the end 90L of the blade. The robot 60 is pivoted into the process chamber 6, indexed along the Z-axis to the first pedestal to be off-loaded, and then the gripper head 120 is extended so that arms 64-64 release the clips 50-50 (FIG. 5). The wafer is now resting on the supports 48-48 (FIG. 2). The

arms 168-168 (FIG. 13) are actuated to engage the wafer, then the gripper head 120 is retracted and the robot pivots counterclockwise to the transfer position 73, then the gripper head is extended and the arms 68-68 are activated to release the wafer on the unload blade end 90U. Next, after retracting the gripper head 120, as shown in FIG. 12B, the shuttle 70 pivots the blade counterclockwise to position the unprocessed wafer at transfer position 73 and position the unloaded wafer in the unload position 68. The unload cassette 68 then indexes upwardly to pick up the processed wafer from blade 90U. At the same time, the robot 60 reverses its previous operation to pick up the unprocessed wafer at the transfer position 73, rotate into the processing chamber 6 and load the wafer onto the (a) vacant pedestal 22. The robot 60 then indexes upwardly or downwardly on the elevator to the next of the three pedestal positions on each hexode face 20, repeats the unload and load sequences, then indexes to the last of the three pedestals and completes the final unload and load sequences for that hexode face. The hexode is then rotated 60° by its motor to present the next face 20 for unloading and loading and the previous sequence is repeated for the second face. The hexode indexing and the triple unload and load sequence are then performed in seriatim four additional times to complete the unloading and loading of the six face hexode. Software features resident in the controller allow other than serial unload/load operations, if desired.

Following the completion of the unloading and loading, the robot 60 is rotated counterclockwise out of the processing chamber, the gate valve 9 is closed and the next etching sequence is commenced. At this time or subsequently, the vacuum can be released from the load lock chamber 7 and the indexer doors 82-82 opened to initiate the next cassette unloading and loading sequence.

Autoaligning System

Prior to the use of the system 5 to process wafers, and periodically during use, the position of each pedestal 22 relative to the robot 60 is measured and stored in the controller 10 memory. This memory mapping is used in accurately positioning the robot gripper head 120 for loading/unloading wafers 17-17 at the hexode 18. Such automatic sensing of the target (pedestal) position is very useful for robotic systems when the targets may be moving or have unpredictable position changes in time. Many sophisticated robots use vision systems to perform these tasks. However, the shortcomings of the vision systems are high cost, low reliably and in many cases limited applicability due to space, weight and environment restrictions. The present adaptive system 115, illustrated in FIG. 21, provides reliable, position sensing. The system 115 includes the robot 60, including the gripper 120 which mounts sensor 104. The sensor 104 is the heart of the system 115. In a preferred embodiment, it is the HP HEDS-1000 High Resolution Optical Reflective Sensor. The optical spot (700-nm wavelength) is focused to 0.19-mm dia. at 4.5-mm from the detector window. See FIG. 22. This detector was originally designed for BAR code scanner readers due to its small focused spot size. However, because of its sensitivity to the axial distance it has proven ideally suitable. Referring further to FIG. 21, the commercial IR sensor unit 104 is adjustably mounted behind the transparent gripper base 160 for transmitting a focused IR beam onto the pedestals 22 and applying to the controller 10 a signal containing information indicative of the distance between the unit 194 and the pedestal 22. For example, by determining the sensor-to-pedestal distance at two points on a single pedestal and by applying triangulation techniques, the precise angle of inclination and travel distance can be calculated for each pedestal 22.

In particular, output from the sensor 116 is transmitted via digitizing circuit 103 (FIG. 20) to the controller 10 for use in controlling the three (R,θ,Z) robot stepper motors. The controller 10 is programmed to determine the pedestal position and angular orientation using the algorithm shown in FIG. 21. Scanning data is derived for transverse scanning (R distance), and axial scanning along the pedestal surface to determine the location of the pedestal slot 116 along the Z axis.

In order to determine the exact location of a pedestal 22, the following steps are taken. First, focusing is done near the bottom of the pedestal 22 in question, at coordinates (U1,V1), where U is the horizontal gripper (end effector) coordinate and V is the vertical gripper coordinate, (the angle of gripper face with respect to the vertical is Th).

A second focusing point is taken near the top of the pedestal (U2,V2). From the slope of the line connecting points 1 and 2,

$$Th = \mathrm{atan}((U2-U1) / (V2-V1))$$

gives the angle of the pedestal or the proper alignment for the gripper. After this, a point near the slot is focused and scanned to determine the proper slot or pedestal height (U3,V3). Then the gripper is moved to the robot center height at the angle determined from last step, and at this point another refocusing is performed to get the final focus distance and the gripper is again moved to that position. The resulting coordinate information defining the (R,θ,Z) pedestal location is then stored in the EEPROM.

Performance

The above-described system 5 is designed to completely unload and reload an 18 wafer hexode 16 in four minutes and 30 seconds, for an average wafer transfer time of about 7.5 seconds. The loading process adds an average of less than one particle per wafer per transfer. Particle size is equal to or greater than one micrometer in diameter. The loader outgases into the vacuum chamber at such a rate that the pressure in the load chamber increases at a rate of less than 0.5 millitorr per minute. The load chamber is reduced to 10^{-1} millitorr and operates at 10^{-1} millitorr. Finally, the autoloader is designed to transfer 100,000 wafers without adjustment. This is equal to 36 wafer transfers/cycle x 40 process cycles/day for 60 days.

It is apparent from the foregoing that a new and improved apparatus has been provided for loading an unloading wafers in a semiconductor processing system. While an etcher system has been described, the invention applies to other systems as well, such as deposition systems and ion implant systems.

Claims

1. A robotic wafer handling system for transferring wafers bidirectionally between first and second angularly oriented positions, comprising:

   a wafer gripper (120) actuable for releasably gripping a wafer (17);

   wafer transfer apparatus (60) including a support (110) and means (142) mounting said wafer gripper (12) for extending and retracting movement relative to said support for loading and unloading wafers at first and second angularly oriented positions, the first position being a wafer loading and unloading position in the load lock chamber and the second position being a wafer loading and unloading position at the wafer support in the processing chamber (6) and means (128) for pivoting the mounting means of the gripper to orient the wafer gripper relative to the first and second angularly oriented positions, so as to orient the gripping finger means for loading and unloading at said first and second positions.

2. The robotic wafer handling system of Claim 1 wherein the first position is at least one substantially vertically oriented wafer support position (22) defined on wafer processing apparatus (18) within a wafer processing chamber (6), and the second position is a substantially horizontally oriented wafer support position (73) having associated therewith separate wafer loading and unloading positions (67 and 68), the wafer handling system further comprising a wafer loading and unloading system which comprises:

   indexing means (66) adapted for supporting at least a pair of wafer holding receptacles such as cassettes so that the major surface of wafers therein are oriented horizontally and for selectively indexing the cassettes vertically through respective horizontal loading and unloading positions; and

   a shuttle (70) comprising a wafer transfer blade (90) having two flat horizontal wafer holding ends (90L, 90U) pivotally mounted for reciprocal horizontal pivoting of the two wafer holding ends between said second position (73) and an associated one of said loading and unloading positions to locate one blade end at said second position for wafer transfer by the gripping finger means when the other end is at is associated loading or unloading position (67 or 68); and wherein said selective vertical cassette indexing movement through the horizontal loading or unloading position effects automatic wafer transfer between the cassette and said horizontal wafer holding sections of the transfer blade.

3. The robotic wafer handling system of Claim 1 wherein the wafer support position (22) is on an electrode (18) within a processing system (5), and wherein the wafer handling system includes clips (50) for holding the wafers (17) at the wafer support positions with the wafer backside adjacent the electrode, and the wafer gripper (120) includes means (64) for engaging the clips from the front side of the wafer support position for moving the clips to an open position to permit loading and unloading of the wafers at the electrode.

4. The robotic wafer handling system of Claim 1 further including:

   an optical sensor (104) attached to the gripper (120) for generating an electric signal representation of the distance between the gripper and the first position;

   computer means (10) responsive to said electrical signal for determining the angular orientation of the first position relative to the gripper and the distance between the first position and the gripper, the computer means (10) including electronic memory for storing said angular orientation and distance information; and

   electronic driver means (196) responsive to the stored information for controlling the

wafer transfer apparatus to precisely move the gripper to the first position for loading and unloading wafers.

5. The robotic wafer handling apparatus of Claim 1 wherein the first position is a substantially vertically oriented wafer support position defined on wafer processing apparatus (78) within a wafer processing chamber (6), and wherein the second position is a substantially horizontally oriented wafer support position (73) associated with a multiple wafer holder receptacle (67, 68), the wafer processing apparatus comprising a wafer holding electrode having a plurality of substantially vertical sides (20), each side being adapted for supporting at least one wafer thereon, and being rotatable about a substantially vertical axis to selectively position the sides of the first position, and wherein each side of the electrode includes holders (22) for mounting a plurality of wafers; and wherein the robotic wafer handling system further comprises:

   an elevator (122, 124) adapted for mounting the wafer transfer apparatus (60) for vertical movement therealong, and

   motor means (126, 130) for moving the wafer transfer apparatus on the elevator between the plurality of vertical wafer holders.

6. The robotic wafer handling system of Claim 5, further comprising:

   a vacuum load lock chamber (7) adjacent the processing chamber mounting the wafer transfer apparatus (60) therein; and

   a gate valve (9) between the wafer processing chamber and the load lock chamber for permitting transfer of wafers therebetween.

7. The semiconductor wafer processing apparatus (78) of Claim 6, wherein said support (110) is a housing having an aperture (187) which is enclosed by a filter (186), for permitting transfer of ambient gas between the housing and the chamber (6) without particulate transfer; and wherein the system further comprises:

   a filter (188) mounted on the chamber gas inlet (181) and enclosing an area which is large relative to the area of the inlet for substantially eliminating particulates from the inlet gas flow and for providing substantially non-turbulent laminar flow; and

   a filter (189) mounted on the vacuum exhaust line (37) from the load lock chamber and enclosing a area which is large relative to the area of the exhaust line, for isolating the load lock chamber from the associated vacuum and for providing substantially non-turbulent laminar exhaust flow;

   an inlet gas system (182-185) connected to the vacuum load lock chamber (7) for supplying gas to said load lock during vacuum release, and wherein the inlet gas system comprises a relatively high flow rate means (184) and selectable relatively low rate means (183, 185) for providing non-turbulent laminar inlet gas flow; and

   a vacuum roughing system (36, 38) connected to the vacuum load lock chamber and comprising a relatively high flow rate means (36) and a selectable relatively low flow rate means (38) for providing non-turbulent laminar vacuum exhaust flow.

8. The semiconductor wafer handling system of any of Claims 1 to 7, wherein the wafer gripper (120) comprises a base (16), a motor (164) mounted on the base, and a movable four-bar link (172, 176) mounting the wafer gripper fingers (170) to the rotatable shaft of the motor and the base for imparting reciprocal radial movement to the wafer gripper fingers for gripping and releasing wafers.

9. The semiconductor wafer handling system of any of Claims 1 to 7, wherein the wafer gripper (120) comprises a base (160); a hub (166) rotatably mounted on the base; a plurality of arms (172) mounted on the hub for rotation on the base substantially transverse to their length; a plurality of means (176) having first and second angled sections (174, 180) and being attached to the base at the first section (174) and to the arm at the second section (180) and mounting the wafer gripper arms (120) thereto for converting transverse reciprocal rotation of the arm (172) into substantially radial inward and outward translational movement of the wafer gripper arms (170) for cooperatively picking up and releasing wafers; and means (164) for rotating said hub.

10. The semiconductor wafer handling system of Claim 3, wherein the electrode (18) is multifaceted, each electrode facet (20) being adapted for mounting a wafer support tray (43) to expose one side of each wafer supported in the tray for processing; each tray including generally circular arrays of spring-mounted clips (50) for releasably supporting each wafer; and the clips being adapted for engagement from the exposed side of the wafer and facet for pivoting the array to an open position for insertion and removal of wafers.

Revendications

1. Système robotique de manipulation de tranches destiné à transférer bidirectionnellement des tranches entre des première et seconde positions orientées angulairement, comportant :

un dispositif (120) de préhension de tranche pouvant être actionné pour prendre de façon libérable une tranche (17) ;

un appareil (60) de transfert de tranches comprenant un support (110) et des moyens (142) de montage dudit dispositif (12) de préhension de tranche pour qu'il effectue un mouvement d'extension et de retrait par rapport audit support afin de charger et décharger des tranches dans des première et seconde positions orientées angulairement, la première position étant une position de chargement et de déchargement de tranches dans la chambre de sas de chargement et la seconde position étant une position de chargement et de déchargement de tranches au support de tranche dans la chambre (6) de traitement et des moyens (128) destinés à faire pivoter les moyens de montage du dispositif de préhension pour orienter le dispositif de préhension de tranche par rapport aux première et seconde positions orientées angulairement, afin d'orienter les moyens à doigts de préhension pour un chargement et un déchargement dans lesdites première et seconde positions.

2. Système robotique de manipulation de tranches selon la revendication 1, dans lequel la première position est au moins une position (22) de support de tranche sensiblement orientée verticalement définie sur un appareil (18) de traitement de tranche à l'intérieur de la chambre (6) de traitement de tranche, et la seconde position est une position (73) de support de tranche orientée sensiblement horizontalement, à laquelle sont associées des positions séparées (67 et 68) de chargement et de déchargement de tranche, le système de manipulation de tranche comportant en outre un système de chargement et de déchargement de tranches qui comporte :

des moyens d'indexage (66) conçus pour supporter au moins une paire de logements de maintien de tranches tels que des cassettes afin que les surfaces principales de tranches s'y trouvant soient orientées horizontalement, et pour indexer sélectivement les cassettes en les faisant passer verticalement par des positions horizontales respectives de chargement et de déchargement ; et

une navette (70) comportant une lame (90) de transfert de tranche ayant deux extrémités horizontales et plates (90L, 90U) de maintien de tranche montées de façon pivotante afin que les deux extrémités de maintien de tranche effectuent un mouvement horizontal alternatif pivotant entre ladite seconde position (73) et l'une, associée, desdites positions de chargement et de déchargement pour positionner une première extrémité de la lame dans ladite seconde position pour un transfert de tranche par les moyens à doigts de préhension lorsque l'autre extrémité est dans sa position associée de chargement ou de déchargement (67 ou 68) ; et dans lequel ledit mouvement vertical sélectif d'indexage de cassette passant par la position horizontale de chargement ou de déchargement effectue un transfert automatique de tranche entre la cassette et lesdites parties horizontales de maintien de tranche de la lame de transfert.

3. Système robotique de manipulation de tranches selon la revendication 1, dans lequel la position (22) de support de tranche se trouve sur une électrode (18) à l'intérieur d'un système (5) de traitement, et dans lequel le système de manipulation de tranche comprend des pinces (50) destinées à maintenir les tranches (17) dans les positions de support de tranches, le revers des tranches étant adjacent à l'électrode, et le dispositif (120) de préhension de tranche comprend des moyens (64) destinés à engager les pinces depuis le côté avant de la position de support de tranches pour déplacer les pinces vers une position d'ouverture afin de permettre le chargement et le déchargement des tranches à l'électrode.

4. Système robotique de manipulation de tranches selon la revendication 1, comprenant en outre :

un capteur optique (104) relié au dispositif de préhension (120) pour générer un signal électrique représentant la distance entre le dispositif de préhension et la première position ;

des moyens à calculateur (10) qui, en réponse audit signal électrique, déterminent l'orientation angulaire de la première position par rapport au dispositif de préhension et la distance entre la première position et le dispositif de préhension, les moyens à calculateur (10) comprenant une mémoire électronique destinée à stocker ladite information d'orientation angulaire et de distance ; et

des moyens électroniques de commande (196) qui, en réponse à l'information stockée, sont destinés à commander l'appareil de transfert de tranches pour amener avec précision le dispositif de préhension dans la première posi-

tion afin de charger et décharger les tranches.

5. Appareil robotique de manipulation de tranches selon la revendication 1, dans lequel la première position est une position de support de tranche orientée sensiblement verticalement définie sur un appareil (78) de traitement de tranches à l'intérieur d'une chambre (6) de traitement de tranches, et dans lequel la seconde position est une position (73) de support de tranche orientée sensiblement horizontalement, associée à un logement multiple (67, 68) de maintien de tranches, l'appareil de traitement de tranches comportant une électrode de maintien de tranches présentant plusieurs côtés sensiblement verticaux (20), chaque côté étant conçu pour supporter sur lui au moins une tranche, et pouvant tourner autour d'un axe sensiblement vertical pour positionner sélectivement les côtés de la première position, et dans lequel chaque côté de l'électrode comprend des éléments de maintien (22) pour le montage de plusieurs tranches ; et dans lequel le système robotique de manipulation de tranches comporte en outre :

un élévateur (122, 124) conçu pour le montage de l'appareil (60) de transfert de tranches afin qu'il effectue un mouvement vertical le long de cet élévateur, et

des moyens moteurs (126, 130) destinés à déplacer l'appareil de transfert de tranches sur l'élévateur entre plusieurs éléments verticaux de maintien de tranches.

6. Système robotique de manipulation de tranches selon la revendication 5, comportant en outre :

une chambre (7) de sas de chargement à vide adjacente à la chambre de traitement dans laquelle l'appareil (60) de transfert de tranches est monté ; et

un robinet-vanne (9) entre la chambre de traitement de tranches et la chambre de sas de chargement destinée à permettre un transfert de tranches entre elles.

7. Appareil (78) de traitement de tranche à semiconducteurs selon la revendication 6, dans lequel ledit support (110) est une enceinte ayant une ouverture (187) qui est fermée par un filtre (186) pour permettre un transfert de gaz ambiant entre l'enceinte et la chambre (6) sans transfert de particules ; et dans lequel le système comporte en outre :

un filtre (188) monté sur l'entrée (181) de gaz de la chambre et couvrant une section qui est grande par rapport à la section de l'entrée pour éliminer sensiblement des particules de l'écoulement de gaz d'entrée et pour produire un écoulement sensiblement laminaire, non turbulent ; et

un filtre (189) monté sur la conduite (37) d'évacuation de vide à partir de la chambre de sas de chargement et couvrant une section qui est grande par rapport à la section de la conduite d'évacuation, afin d'isoler la chambre de sas de chargement du vide associé et de produire un écoulement d'évacuation laminaire, pratiquement non turbulent ;

un système (182-185) de gaz d'entrée raccordé à la chambre (7) de sas de chargement à vide pour fournir du gaz audit sas de chargement durant la libération du vide, et dans lequel le système de gaz d'entrée comporte des moyens (184) à débit d'écoulement relativement élevé et des moyens (183, 185) à débit relativement bas, réglable, pour produire un écoulement de gaz d'entrée laminaire, non turbulent ; et

un système (36, 38) d'ébauchage de vide raccordé à la chambre de sas de chargement à vide et comportant des moyens (36) à débit d'écoulement relativement élevé et des moyens (38) à débit d'écoulement relativement bas et réglable pour produire un écoulement d'évacuation de vide laminaire et non turbulent.

8. Système de manipulation de tranches à semiconducteurs selon l'une quelconque des revendications 1 à 7, dans lequel le dispositif (120) de préhension de tranches comporte une embase (16), un moteur (164) monté sur l'embase et un quadrilatère articulé (172, 176) au moyen duquel les doigts (170) de préhension de tranches sont montés sur l'arbre tournant du moteur et sur l'embase pour communiquer un mouvement radial alternatif aux doigts de préhension de tranches afin qu'ils prennent et libèrent les tranches.

9. Système de manipulation de tranches à semiconducteurs selon l'une quelconque des revendications 1 à 7, dans lequel le dispositif (120) de préhension de tranches comporte une embase (160) ; un moyeu (166) monté de façon à pouvoir tourner sur l'embase ; plusieurs bras (172) montés sur le moyeu afin de tourner sur l'embase sensiblement transversalement à leur longueur ; plusieurs moyens (176) ayant des première et seconde sections coudées (174, 180) et reliés à l'embase par la première section (174) et au bras par la seconde section (180), et sur lesquels sont montés les bras (120) de préhension de tranches pour transformer une rotation alternative transversa-

le du bras (172) en un mouvement sensiblement radial de translation vers l'intérieur et vers l'extérieur des bras (170) de préhension de tranches afin de prendre et de libérer les tranches en coopérant ; et des moyens (164) destinés à faire tourner ledit moyeu.

10. Système de manipulation de tranches à semiconducteurs selon la revendication 3, dans lequel l'électrode (18) est à facettes multiples, chaque facette (20) de l'électrode étant conçue pour le montage d'un plateau (43) de support de tranches afin d'exposer une face de chaque tranche supportée dans le plateau pour un traitement ; chaque plateau comportant des rangées globalement circulaires de pinces (50) montées sur ressort pour supporter de façon amovible chaque tranche ; et les pinces étant conçues pour être engagées depuis le côté exposé de la tranche et de la facette pour un pivotement de la rangée vers une position ouverte permettant l'insertion et l'enlèvement de tranches.

Patentansprüche

1. Robotsystem für die Wafer-Handhabung zum bidirektionalen Überführen von Wafern zwischen ersten und zweiten im Winkel ausgerichteten Positionen
   - mit einem Wafergreifer (120), der für ein lösbares Greifen eines Wafers (17) betätigbar ist,
   - mit einer Waferüberführungsvorrichtung (60), die eine Abstützung (110) und Einrichtungen (142) aufweist, welche den Wafergreifer für eine Ausfahr- und Einziehbewegung bezüglich der Abstützung zum Beladen und Entladen von Wafern an den ersten und zweiten im Winkel ausgerichteten Positionen halten, wobei die erste Position eine Waferbelade- und -entladeposition in der Ladeschleusenkammer und die zweite Position eine Waferbelade- und -entladeposition an der Waferabstützung in der Behandlungskammer (6) ist, und
   - mit Einrichtungen (128) zum Schwenken der Halteeinrichtungen des Greifers, um den Wafergreifer relativ zu den ersten und zweiten im Winkel ausgerichteten Positionen auszurichten, so daß die Greiffingereinrichtungen zum Beladen und Entladen an den ersten und zweiten Positionen ausgerichtet werden.

2. Robotsystem für die Waferhandhabung nach Anspruch 1, bei welchem die erste Position wenigstens eine im wesentlichen vertikal ausgerichtete Waferabstützposition (22), welche an einer Waferbehandlungsvorrichtung (18) in einer Waferbehandlungskammer (6) ausgebildet ist, und die zweite Position eine im wesentlichen horizontal ausgerichtete Waferabstützposition (73) sind, der separate Waferbelade- und -entladepositionen (67 und 68) zugeordnet sind, wobei das Waferhandhabungssystem weiterhin ein Waferbelade- und -entladesystem
   - mit Schalteinrichtungen (66), die zum Abstützen wenigstens eines Paars von Waferhaltebehältern, wie Kassetten, so daß die größere Oberfläche der Wafer darin horizontal ausgerichtet sind, und zum selektierten Schalten der Kassetten vertikal durch jeweilige horizontale Belade- und Entladepositionen geeignet sind, und
   - mit einem Pendelglied (70) aufweist, das ein Waferüberführungsblatt (90) mit zwei ebenen horizontalen Waferhalteenden (90L, 90U) hat und für eine horizontale Hin- und Herverschwenkung der beiden Waferhalteenden zwischen der zweiten Position (73) und einer zugeordneten Belade- oder Entladeposition schwenkbar angebracht ist, um ein Blattende an der zweiten Position für die Waferüberführung durch die Greiffingereinrichtungen zu positionieren, wenn das andere Ende sich in seiner zugeordneten Belade- oder Entladeposition (67 oder 68) befindet, und wobei die selektive vertikale Kassettenschaltbewegung durch die horizontale Belade- oder Entladeposition eine automatische Waferüberführung zwischen der Kassette und den horizontalen Waferhalteabschnitten des Überführungsblattes bewirkt.

3. Robotsystem für die Waferhandhabung nach Anspruch 1, bei welchem sich die Waferabstützposition (22) auf einer Elektrode (18) in einem Behandlungssystem (5) befindet, das Waferhandhabungssystem Klemmbügel (50) zum Halten der Wafer (17) an den Waferabstützpositionen aufweist, wobei die Waferrückseite an die Elektrode angrenzt, und der Wafergreifer (120) Einrichtungen (64) für den Eingriff mit den Klemmbügeln von der Vorderseite der Waferabstützposition hat, um die Klemmbügel in eine offene Stellung zu bewegen, damit ein Beladen und Entladen der Wafer an der Elektrode möglich ist.

4. Robotsystem für die Waferhandhabung nach Anspruch 1, welches weiterhin
   - einen optischen Sensor (104), der an

dem Greifer (120) festgelegt ist, um eine elektrisches Signal zu erzeugen, das den Abstand zwischen dem Greifer und der ersten Position darstellt,

- Rechnereinrichtungen (10), die auf das elektrische Signal zur Bestimmung der Winkelausrichtung der erstere Position bezüglich des Greifers und des Abstands zwischen der ersten Position und dem Greifer ansprechen, wobei die Rechnereinrichtungen (10) einen elektronischen Speicher zum Speichern der Winkelausrichtung- und Abstandsinformation aufweisen, und
- elektronische Antriebseinrichtungen (196) aufweist, die auf die gespeicherte Information zur Steuerung der Waferüberführungsvorrichtung ansprechen, um den Greifer genau zur ersten Position zum Beladen und Entladen von Wafern zu bewegen.

5. Robotvorrichtung für die Waferhandhabung nach Anspruch 1, bei welcher die erste Position eine im wesentlichen vertikal ausgerichtete Waferabstützposition ist, die an einer Waferbehandlungsvorrichtung (78) in einer Waferbehandlungskammer (6) ausgebildet ist, die zweite Position eine im wesentlichen horizontal ausgerichtete Waferabstützsposition (73) ist, dar ein Mehrfachwaferhaltebehälter (67, 68) zugeordnet ist, wobei die Waferbehandlungsvorrichtung eine Waferhalteelektrode aufweist, die eine Vielzahl von im wesentlichen vertikalen Seiten (20) hat, von denen jede für die Abstützung wenigstens eines Wafers darauf geeignet ist, und die drehbar um eine im wesentlichen vertikale Achse ist, um die Seiten der ersten Position selektiv zu positionieren, wobei jede Seite der Elektrode Halter (22) zum Halten einer Vielzahl von Wafern hat, und bei welcher das Robotsystem für die Waferhandhabung weiterhin
   - ein Hebewerk (122, 124), das zum Halten der Waferüberführungsvorrichtung (60) für eine Vertikalbewegung an ihm entlang geeignet ist und Motoreinrichtungen (126, 130) aufweist, um die Waferüberführungsvorrichtung an dem Hebewerk zwischen der Vielzahl von vertikalen Waferhaltern zu bewegen.

6. Robotsystem für die Waferhandhabung nach Anspruch 5, welches weiterhin
   - eine Vakuumbeladeschleusenkammer (7) angrenzend an die Behandlungskammer, in welcher die Waferüberführungsvorrichtung (60) angebracht ist, und
   - einen Schieber (9) zwischen der Waferbehandlungskammer und der Beladeschleusenkammer aufweist, um die Überführung der Wafer dazwischen zu ermöglichen.

7. Halbleiterplättchenbehandlungsvorrichtung (78) nach Anspruch 6, bei welcher die Abstützung (110) ein Gehäuse mit einer Öffnung (187) ist, welche von einem Filter (186) umschlossen ist, um die Überführung von Umgebungsgas zwischen dem Gehäuse und der Kammer (6) ohne Partikeltransport zu ermöglichen, und bei welcher das System weiterhin
   - einen Filter (188), der an dem Kammergaseinlaß (181) angebracht ist und einen Bereich umschließt, der bezüglich der Fläche des Einlasses groß ist, um Teilchen aus dem Einlaßgasstrom im wesentlichen zu eliminieren und um eine im wesentlichen nichtturbulente laminare Strömung zu erzeugen,
   - ein Filter (189), das an der Vakuumabführleitung (37) aus der Beladeschleusenkammer angebracht ist und eine Fläche umschließt, die bezüglich der Fläche der Abführleitung groß ist, um die Beladeschleusenkammer von dem zugeordneten Vakuum zu isolieren und um eine wesentlichen nicht-turbulente laminare Abführströmung zu schaffen,
   - ein Einlaßgassystem (182 bis 185), das mit der Vakuumbeladeschleusenkammer (7) verbunden ist, um Gas zu der Beladeschleuse während der Vakuumfreigabe zuzuführen, wobei das Einlaßgassystem eine Einrichtung (184) für einen relativ großen Mengenstrom und eine auswählbare Einrichtung (183, 185) für einen relativ niedrigen Mengenstrom hat, um einen nicht-turbulenten laminaren Einlaßgasstrom zu schaffen, und
   - ein Vakuumgrobpumpsystem (36, 38) aufweist, das mit der Vakuumbeladeschleusenkammer verbunden ist und eine Einrichtung (36) für einen relativ hohen Mengenstrom und eine wählbare Einrichtung (38) für einen relativ niedrigen Mengenstrom hat, um eine nicht-turbulente laminare Vakuumabführströmung zu erzeugen.

8. Halbleiterplättchenbehandlungssystem nach einem der Ansprüche 1 bis 7, bei welchem der Wafergreifer (120) eine Basis (16), einen Motor (164), der an der Basis angebracht ist, und ein bewegliches vier Stäbe aufweisendes Gestänge (172, 176) hat, welches die Wafergreiferfin-

ger (170) an der drehbaren Welle des Motors und die Basis hält, um den Wafergreiferfingern zum Greifen und Freigeben der Wafer eine radiale Hin- und Herbewegung zu erteilen.

9. Halbleiterplättchenbehandlungssystem nach einem der Ansprüche 1 bis 7, bei welchem der Wafergreifer (120) eine Basis (160), eine Nabe (166), die drehbar an der Basis angebracht ist, eine Vielzahl von Armen (172), die an der Nabe für eine Drehung auf der Basis im wesentlichen quer zu ihrer Länge angeordnet sind, eine Vielzahl von Einrichtungen (176), die erste und zweite Winkelabschnitte (174, 180) aufweisen und an der Basis an dem ersten Abschnitt (174) und an dem Arm an dem zweiten Abschnitt (180) befestigt sind und die Wafergreiferarme (120) daran halten, um die Hin- und Her-Querdrehung des Arms (172) in eine im wesentlichen radiale einwärts und auswärts gerichtete translative Bewegung der Wafergreiferarme (170) umzuwandeln, damit im Zusammenwirken Wafer aufgegriffen und freigegeben werden, und Einrichtungen (164) zum Drehen der Nabe aufweist.

10. Halbleiterplättchenbehandlungssystem nach Anspruch 3, bei welchem die Elektrode (18) mehrfach facettiert ist, wobei jede Elektrodenfacette (20) zum Halten eines Waferabstütztrogs (43) geeignet ist, um eine Seite eines jeden in dem Trog für die Behandlung abgestützten Wafers freizusetzen, jeder Trog insgesamt kreisförmige Reihen von federgehaltenen Klemmbügeln (50) für das lösbare Abstützen jedes Wafers aufweist und die Klemmbügel für einen Eingriff von der freiliegenden Seite des Wafers und der Facette geeignet sind, um die Reihe in eine Offenstellung für das Einführen und Entfernen von Wafern zu verschwenken.

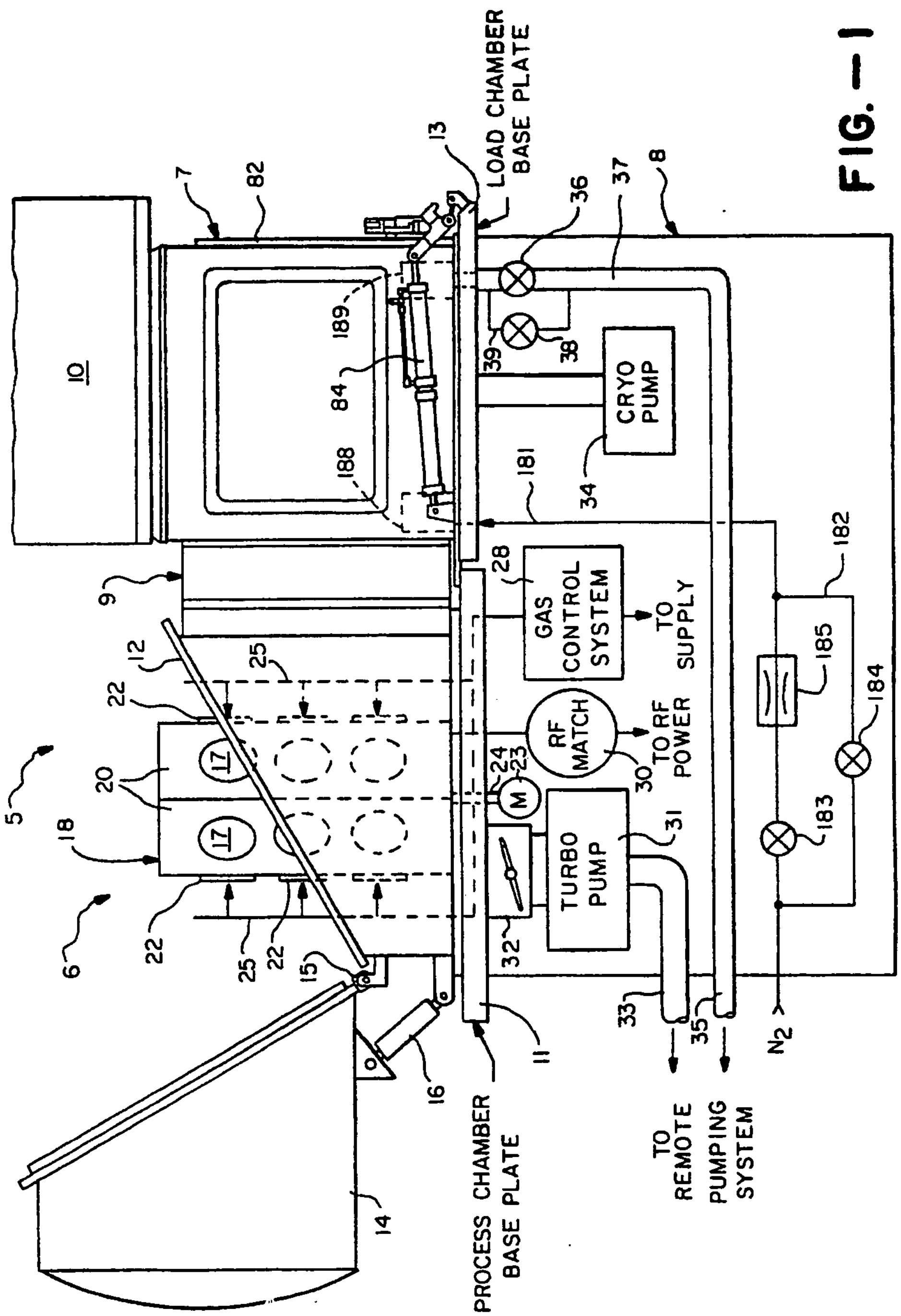
LOAD CHAMBER
BASE PLATE
CRYO
PUMP
GAS
CONTROL
SYSTEM
TO
SUPPLY
RF
MATCH
TO RF
POWER
M
TURBO
PUMP
PROCESS CHAMBER
BASE PLATE
TO
REMOTE
PUMPING
SYSTEM
N_2
10
7
82
13
8
36
37
38
39
189
84
188
181
34
182
185
184
183
28
9
12
25
22
20
17
24
23
30
31
32
18
5
6
15
16
11
14
33
35

FIG. — 1

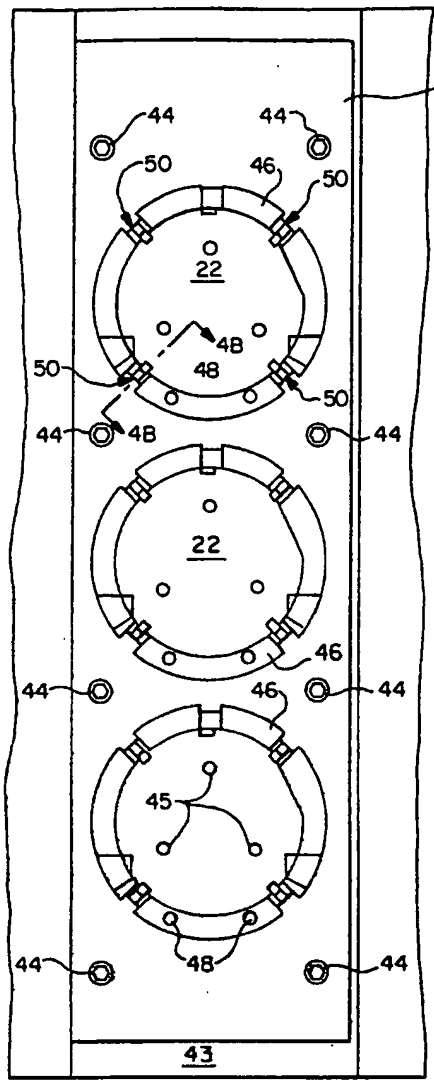

FIG.—2

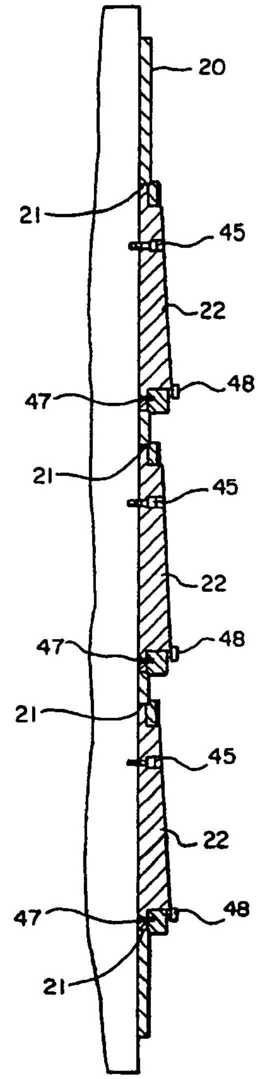

FIG.—3

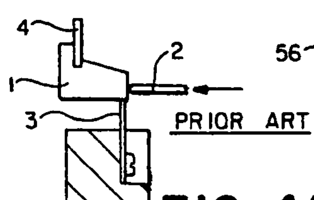

FIG.-4A

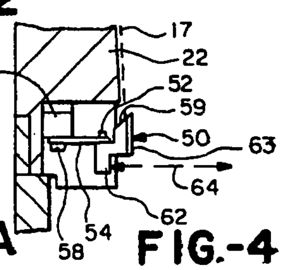

FIG.-4B

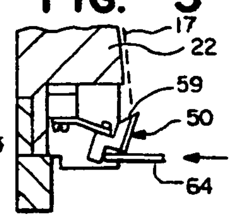

FIG.-4C

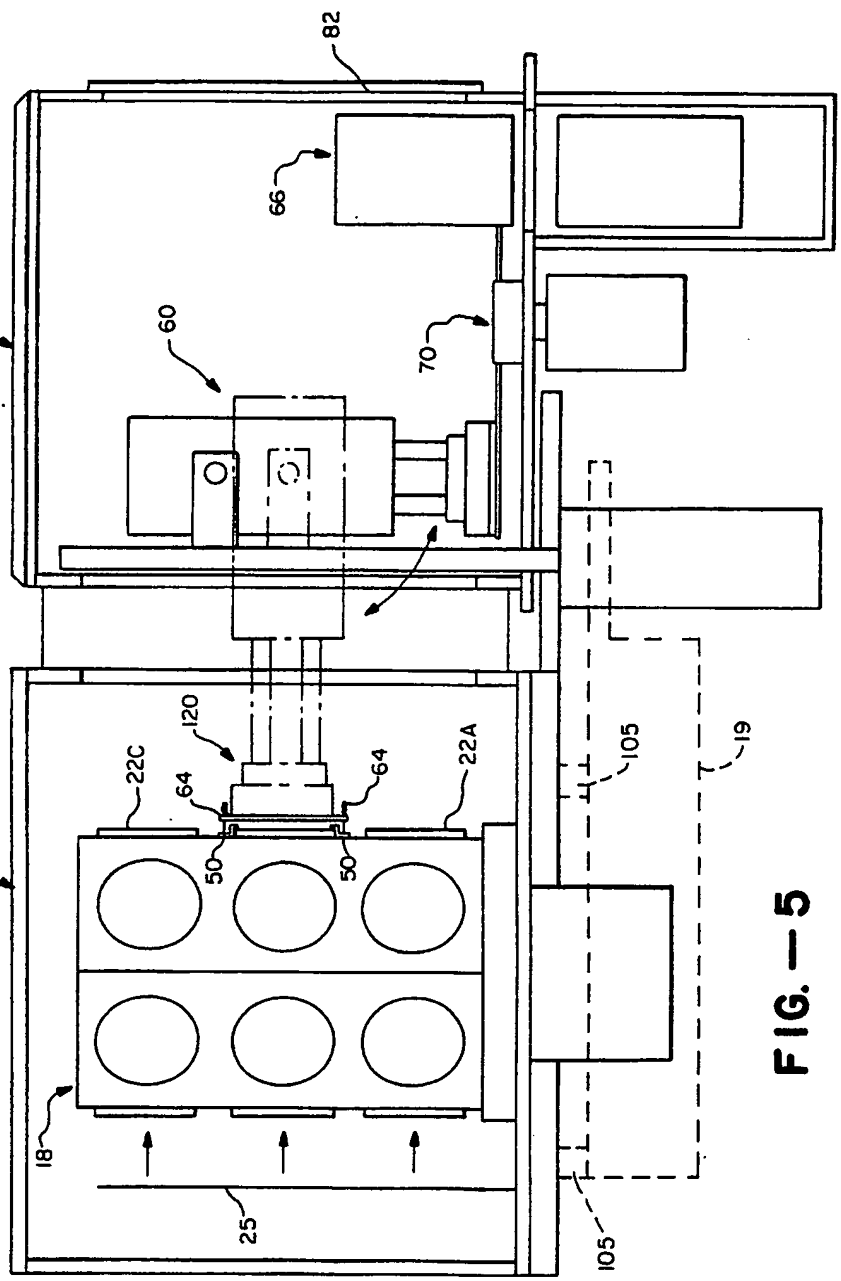

FIG. — 5

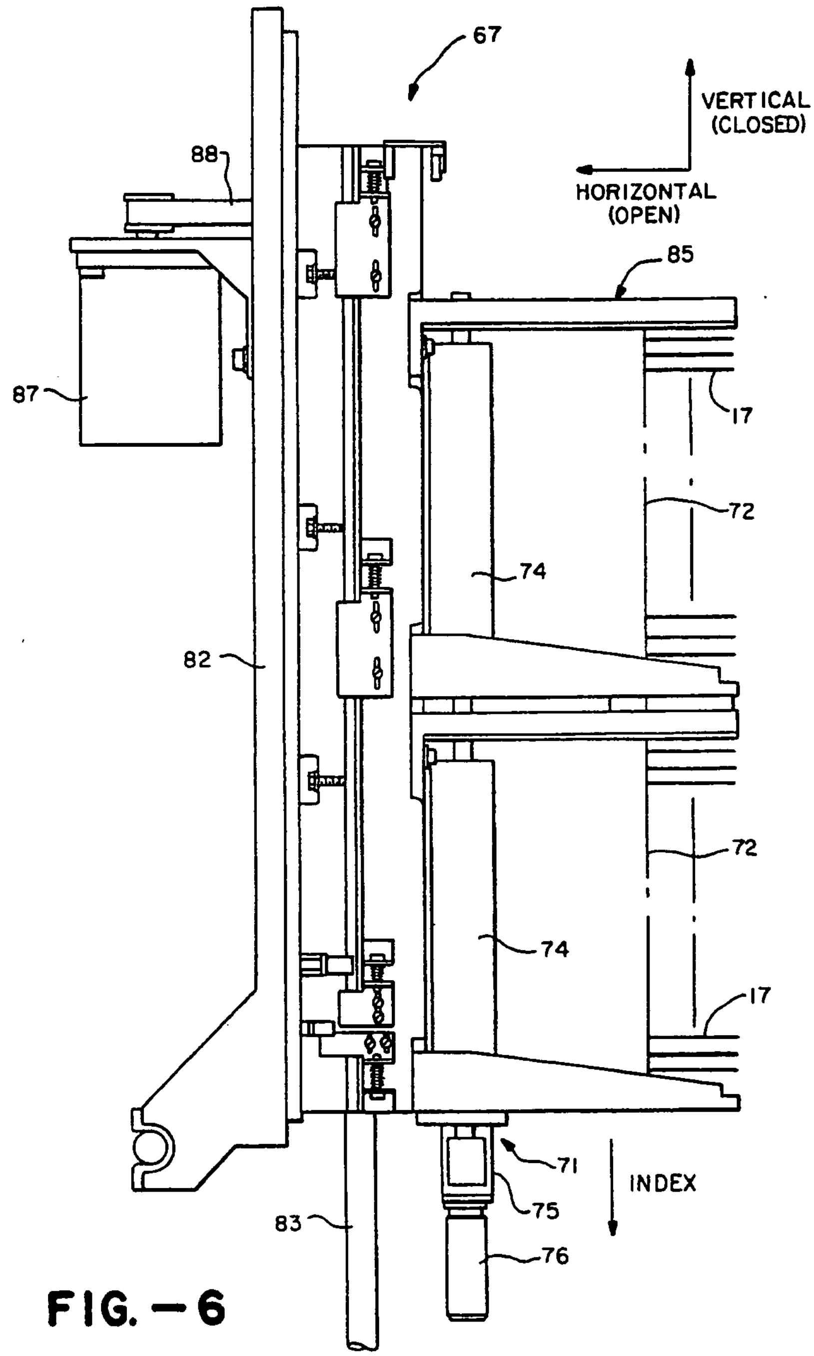
67
VERTICAL
(CLOSED)
HORIZONTAL
(OPEN)
88
85
87
17
72
74
82
72
74
17
71
INDEX
75
83
76

FIG. —6

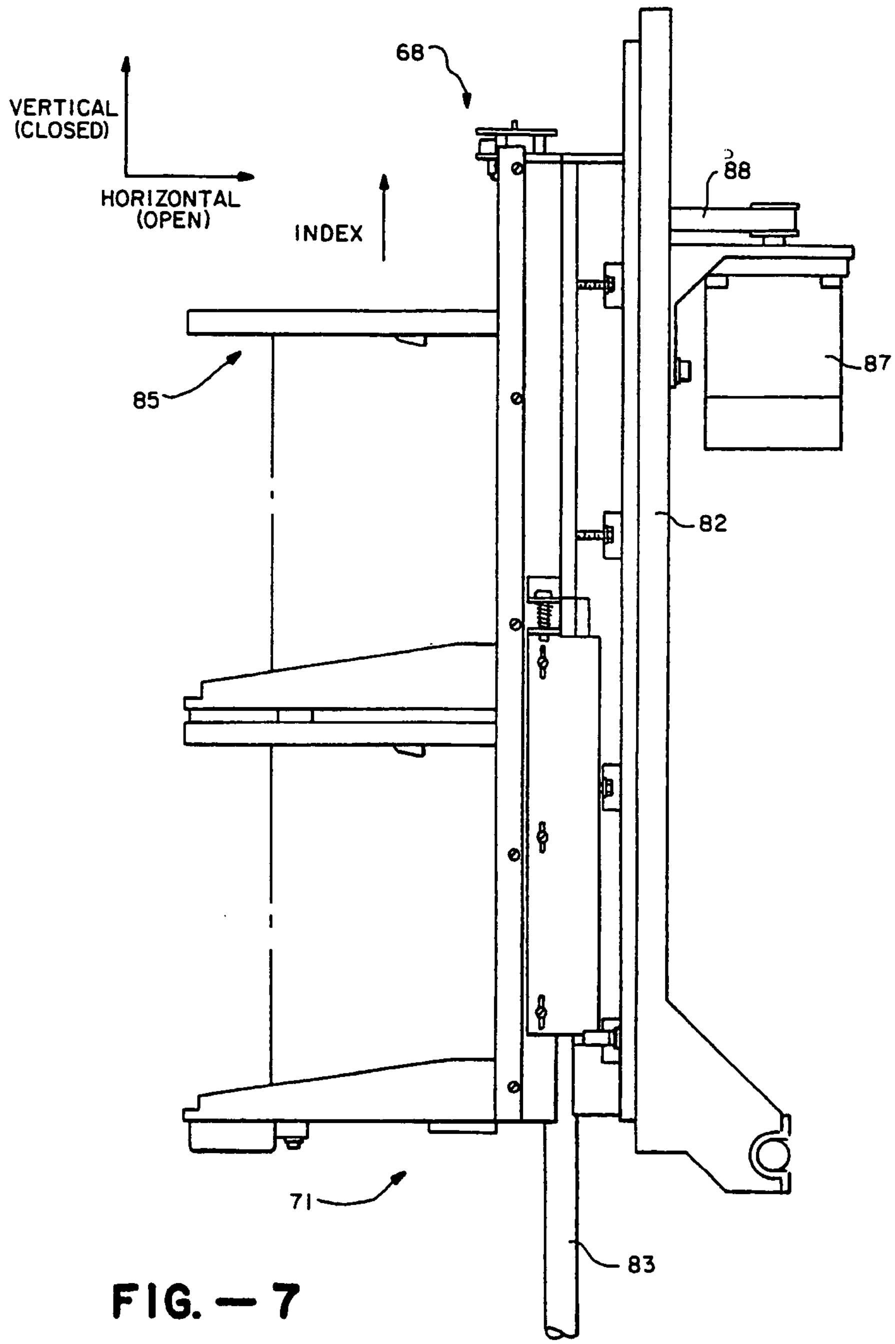

FIG. — 7

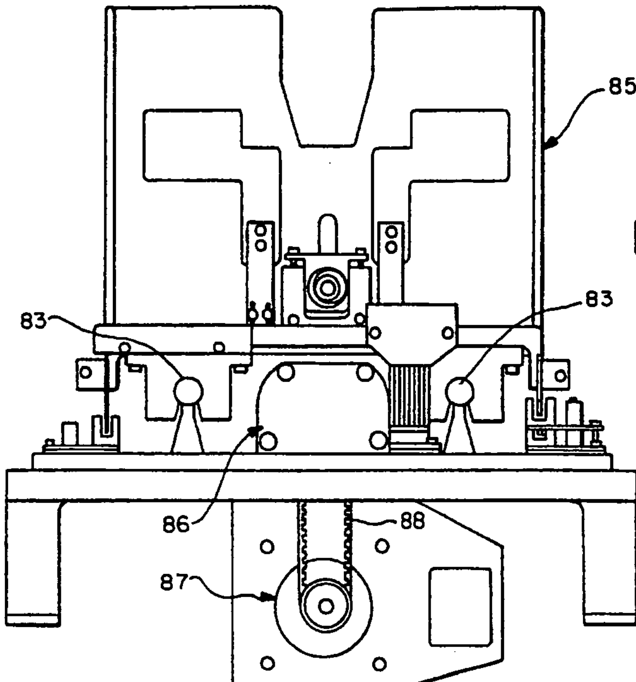

FIG. -8

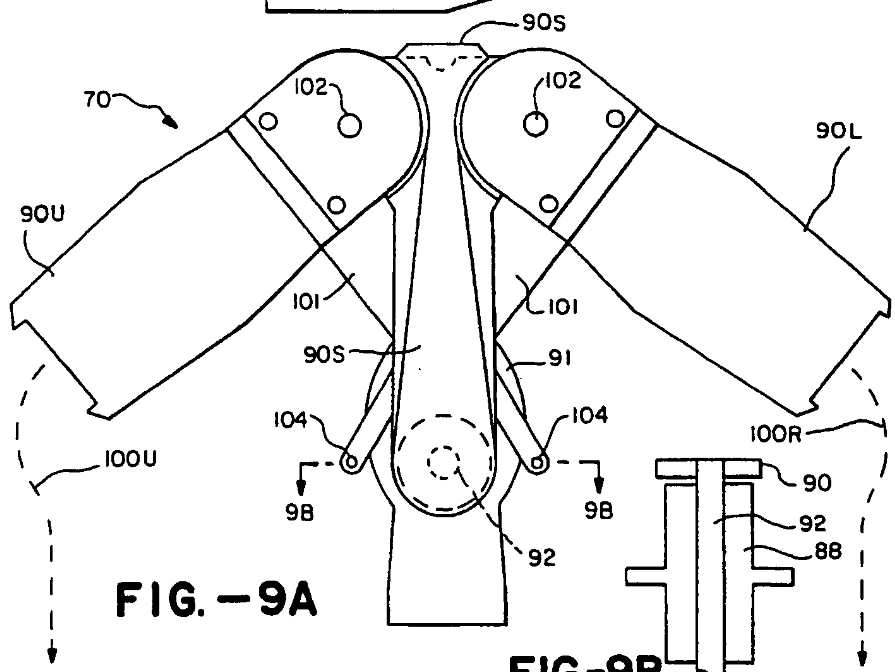

FIG. -9A

FIG.-9B

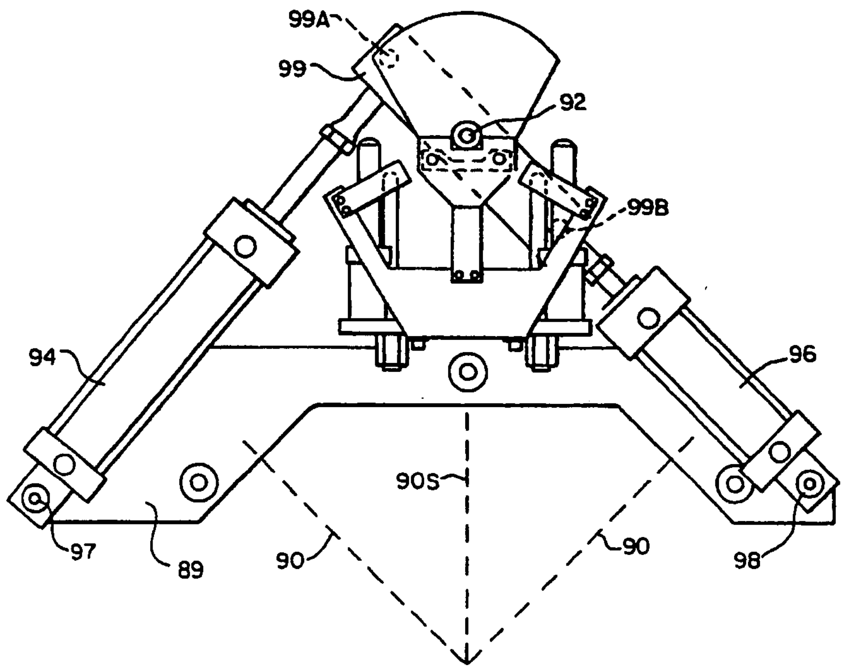

FIG.—10

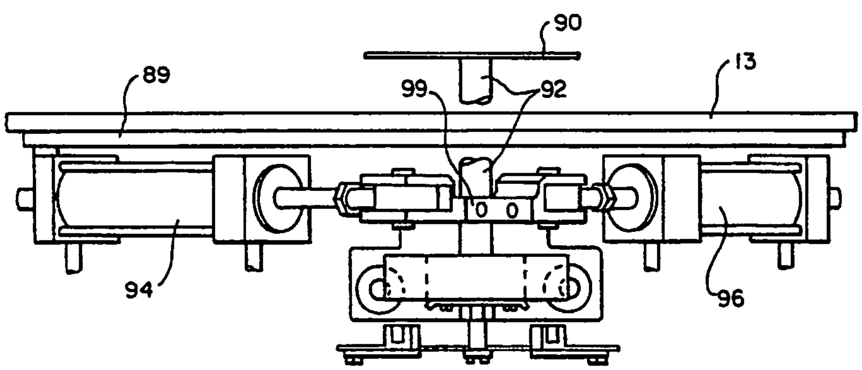

FIG.—11

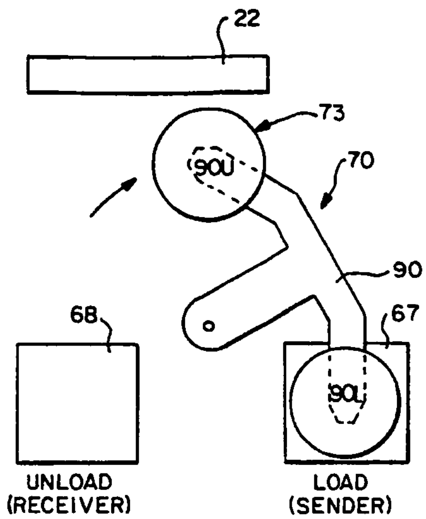

FIG.—12A

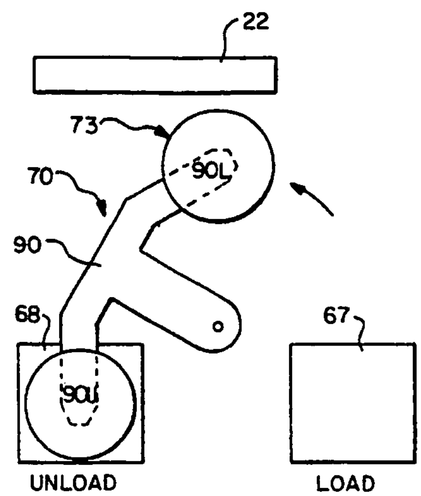

FIG.—12B

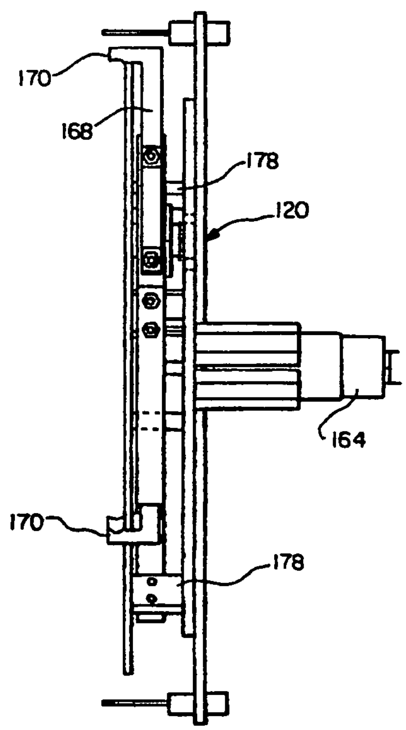

FIG.—18

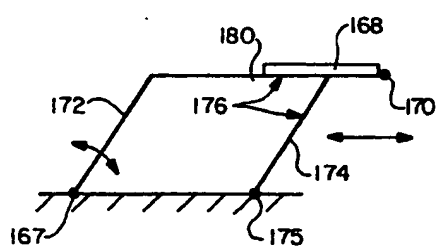

FIG.—19

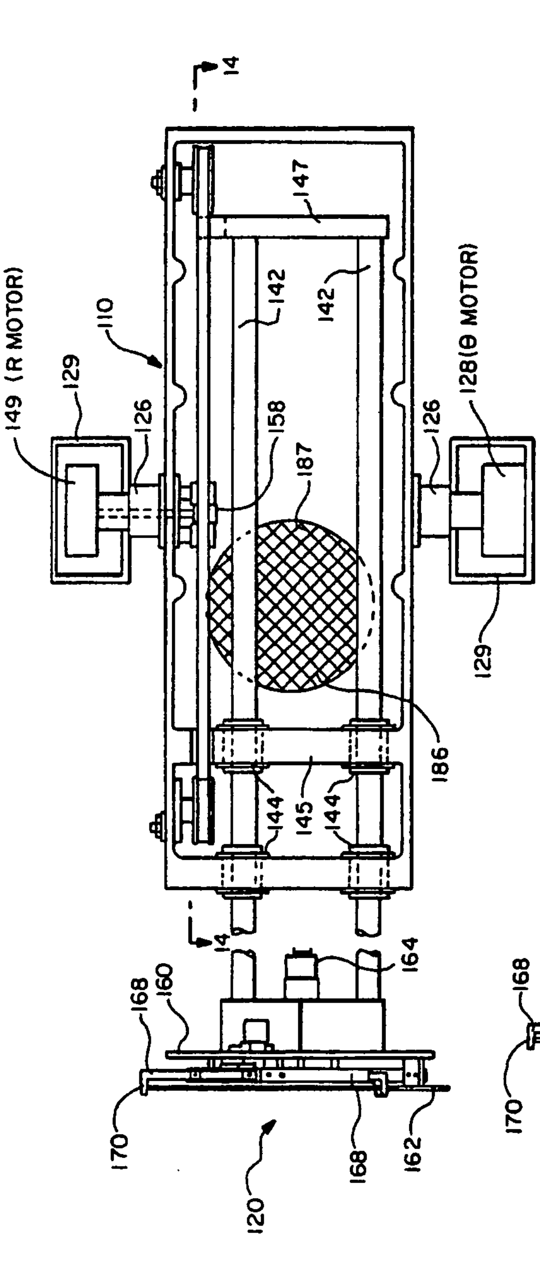
149 (R MOTOR)
129
126
110
158
187
142
147
14
128(θ MOTOR)
186
145
144
164
160
168
170
162
120

FIG. — 13

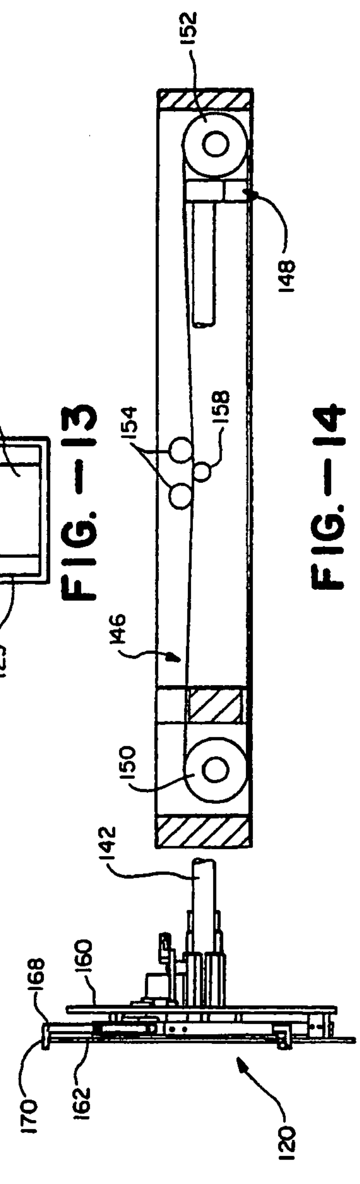
152
148
154
158
146
150
142
168
160
170
162
120

FIG. — 14

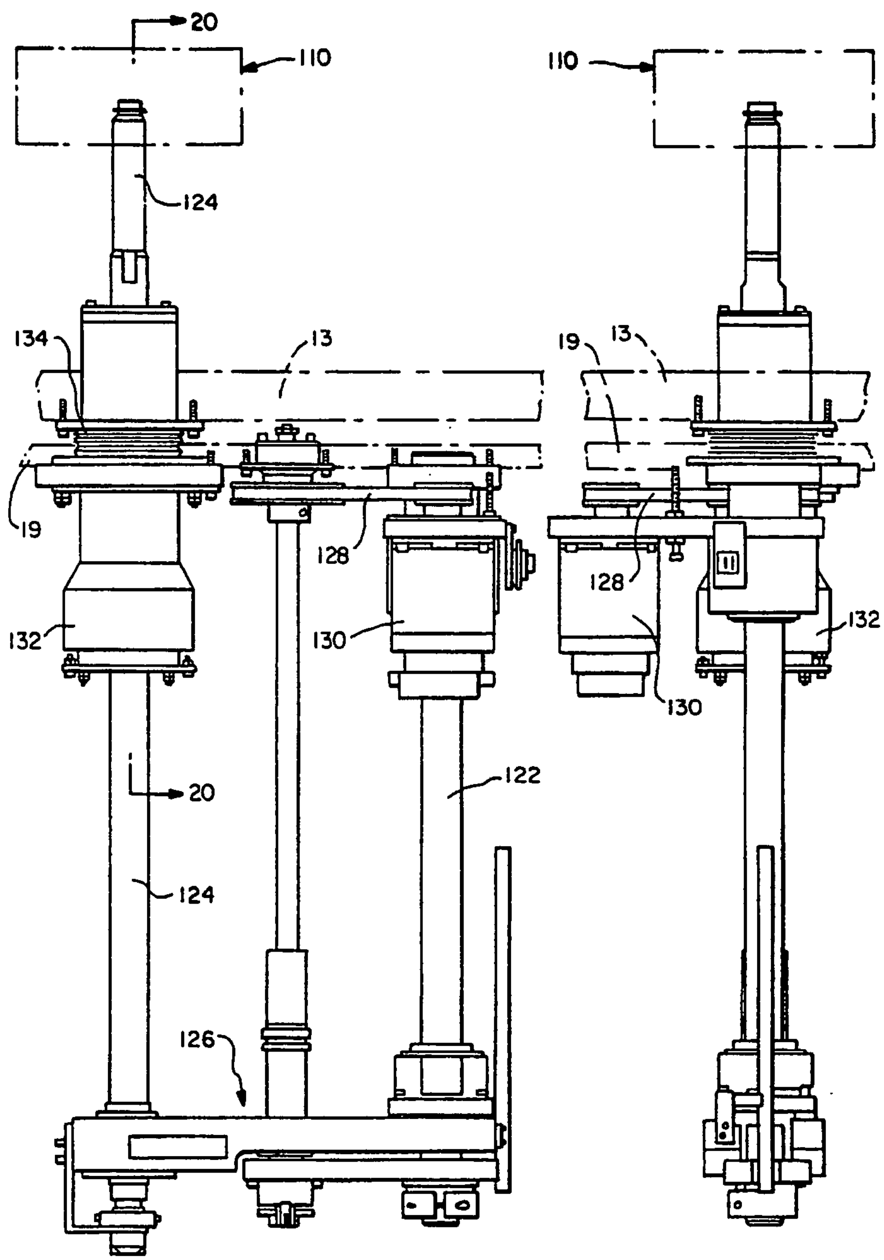

FIG. – 15A FIG. – 15B

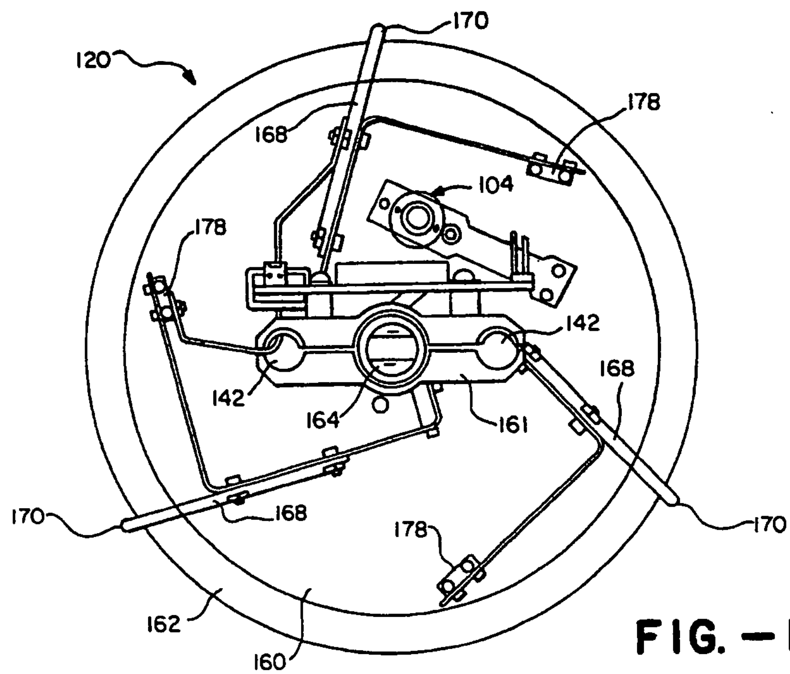
120
170
168
178
104
178
142
168
142
164
161
170
168
170
178
162
160

FIG. — 16

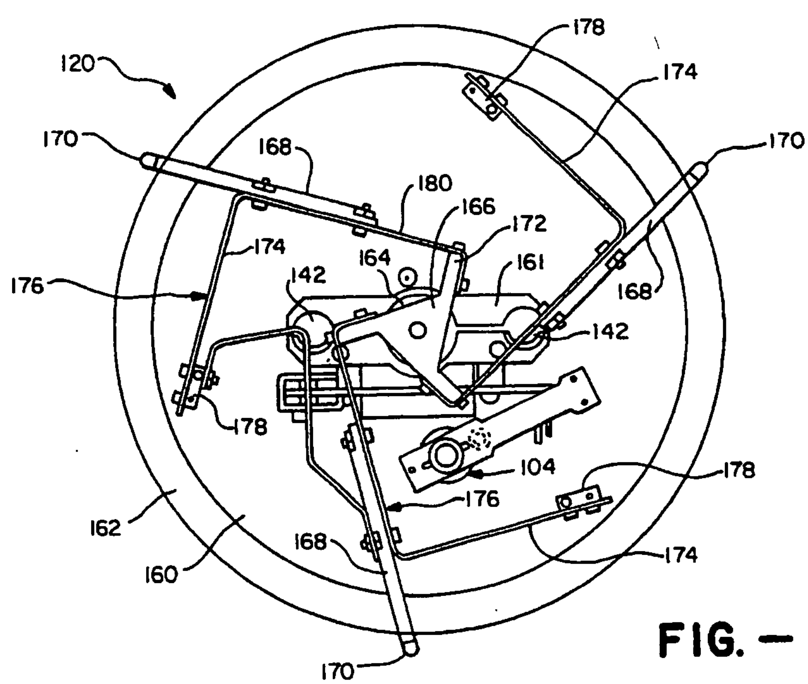
178
120
174
170
170
168
180
166
172
174
164
161
176
142
168
142
178
104
178
176
162
168
174
160
170

FIG. — 17

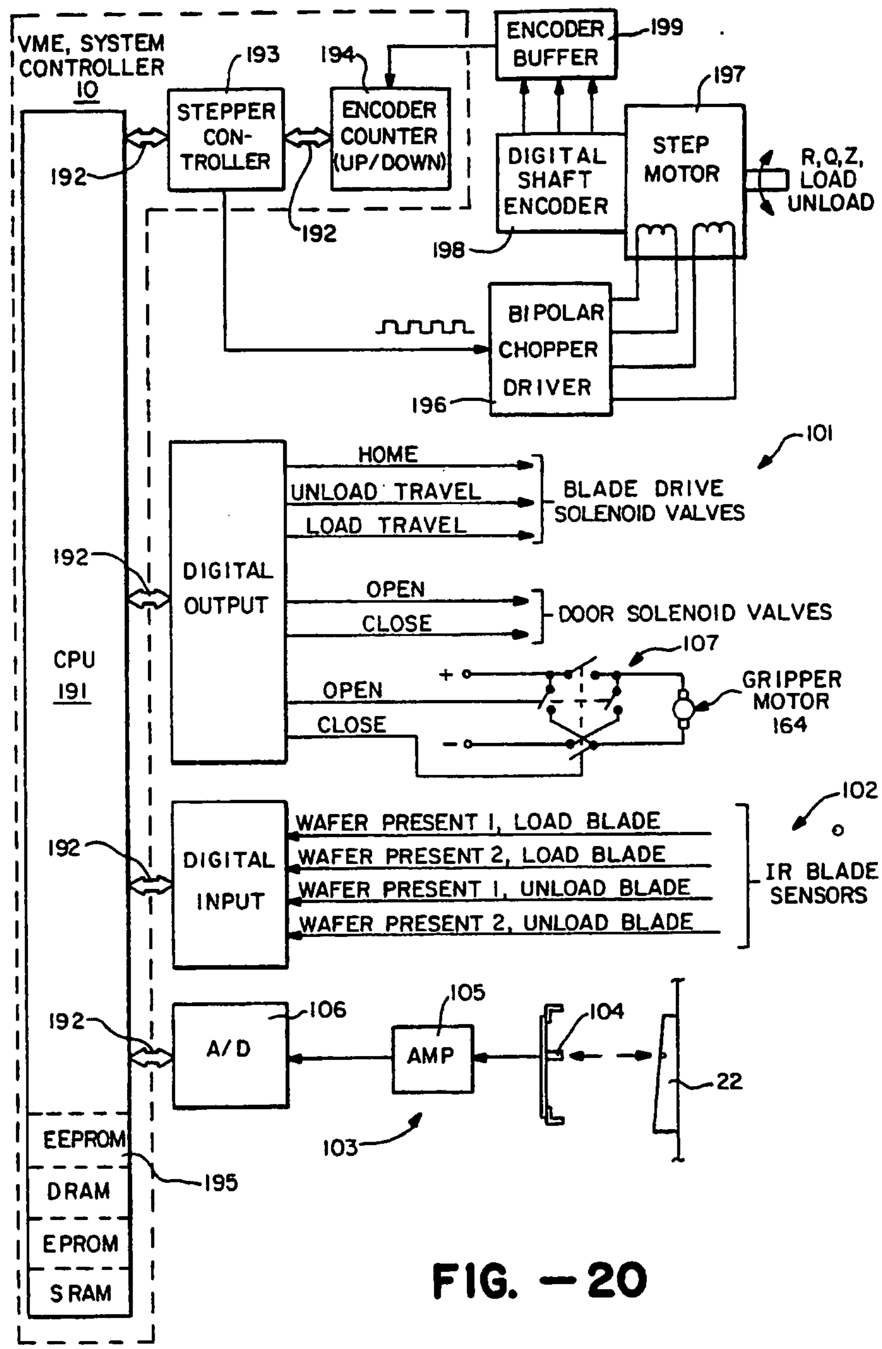
VME, SYSTEM CONTROLLER 10
193
194
STEPPER CON-TROLLER
ENCODER COUNTER (UP/DOWN)
ENCODER BUFFER
199
197
DIGITAL SHAFT ENCODER
STEP MOTOR
R,Q,Z, LOAD UNLOAD
192
198
BIPOLAR CHOPPER DRIVER
196
101
HOME
UNLOAD TRAVEL
LOAD TRAVEL
BLADE DRIVE SOLENOID VALVES
DIGITAL OUTPUT
OPEN
CLOSE
DOOR SOLENOID VALVES
107
CPU 191
OPEN
CLOSE
GRIPPER MOTOR 164
102
DIGITAL INPUT
WAFER PRESENT 1, LOAD BLADE
WAFER PRESENT 2, LOAD BLADE
WAFER PRESENT 1, UNLOAD BLADE
WAFER PRESENT 2, UNLOAD BLADE
IR BLADE SENSORS
A/D
106
105
AMP
104
22
103
EEPROM
DRAM
EPROM
SRAM
195

FIG. —20

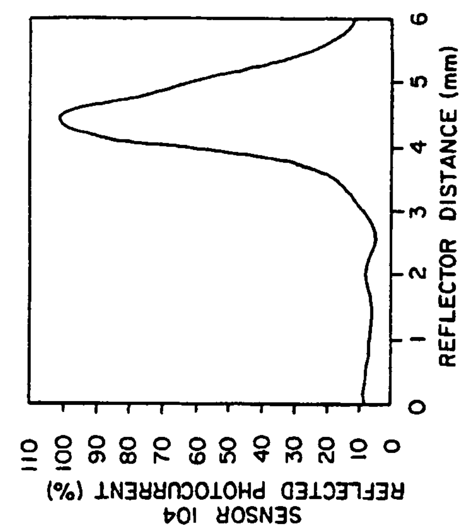
SENSOR 104
REFLECTED PHOTOCURRENT (%)
110
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
REFLECTOR DISTANCE (mm)

FIG.—22

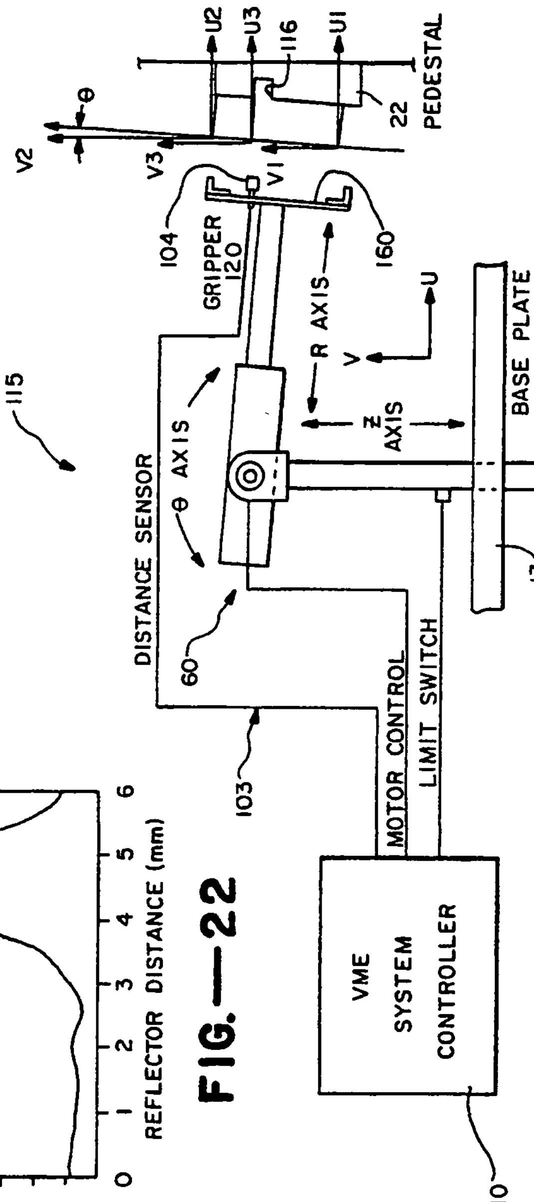
115
DISTANCE SENSOR
θ AXIS
GRIPPER
120
104
160
R AXIS
Z AXIS
U
V
BASE PLATE
13
60
103
MOTOR CONTROL
LIMIT SWITCH
VME
SYSTEM
CONTROLLER
10
V1
V2
V3
θ
U1
U2
U3
116
22
PEDESTAL

FIG.—21